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Financial Determinants of Adoption of Agricultural Technologies in Irish Potato Production in Ol Kalou Sub County, Kenya: Application of Multinomial Logistic Regression

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Authors' contributions

This work was carried out in collaboration among all authors. Author KDM conceptualized, writing original draft, editing the manuscript. Author GGK conceptualized, supervised and reviewed the manuscript. Author MRN supervised and reviewed the manuscript, and Author WVM editing, data collection and reviewing the manuscript. All the author has reviewed the manuscript and agreed to submit this version. All authors read and approved the final manuscript.

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ABSTRACT

Irish potato is a significant source of food and income for many households worldwide. The demand for the crop has steadily increased around the globe. Kenyan Irish potato farmers have the potential to produce about 30 tonnes per Ha. However, small-scale Irish farmers in the country realize low output ranging from 4-8 tonnes per Ha due to limited uptake of agricultural technologies. This study aimed to analyze the financial factors influencing the uptake of agricultural technologies in Irish potato production in Ol Kalou Sub County. The agricultural technologies under investigation were chemical fertilizer, certified seeds, fungicides, and farm machinery. Production and innovation diffusion theories guided the study. Descriptive cross-sectional research design was used to obtain data from a study population of 21,942 smallholder Irish potato farmers in Ol Kalou Sub County. A multiple-stage sampling technique was employed to give a sample size of 385 respondents small scale Irish potato farmers, where data was collected through a semi-structured questionnaire. Data collected was analyzed using multinomial logistic regression through SPSS version 28 and STATA version 17. The model indicated that off-farm income, access to credit, and production risk had a positive and significant influence on adopting agricultural technologies. Conversely, production cost had a negative and significant influence on the adoption of agricultural technologies, while the availability of subsidies had no significant influence. The Marginal effect analysis showed that the availability of off-farm income increased adoption by 22.00%, the increase in credit increased adoption by 2.00%, the availability of mitigation measures of production risk increased adoption by 19.00%, while the increase in production cost decreased adoption by 7.00%. The study concluded that off-farm income, credit facilities, production risk and cost of production influence the adoption of agricultural technologies. The study recommended that the government should develop policy regulations such as diversification of income, grants that reduce production costs, credit incentives, and crop insurance.

Keywords: Adoption; off-farm income; credit; production cost; production risk; subsidies.

1. INTRODUCTION

Irish potato is an essential food crop recommended by the United Nations as a vital food security crop produced in over 100 countries globally [1]. Potato is a primary food crop produced in the majority of developing countries. It is the fourth most-produced food crop globally at about 314 after corn at 822, wheat at 689, and rice at 685 million metric tonnes [2]. Irish potato production in most parts of the world is a fundamental economic activity undertaken by smallholder and large-scale farmers [3]. Globally, more than 300 million metric tonnes of Irish potato are produced annually, consumed by over one billion people [4]. The high consumption rate shows the importance of the crop to most households in different parts of the globe. The use of agricultural technologies in China and India has increased production, and approximately a third of the world's Irish potato comes from the two countries annually [2].

The average Irish potato production in Africa is about 14.2 tonnes per hectare (ha), which depicts a significant gap as compared to other continents, such as America, producing 25.9 tonnes per ha, Europe at 21.1 tonnes per ha, and Asia producing 18.3 tonnes per Ha [4]. The significant difference in production between Africa and other continents is associated with adopting agricultural technologies [5]. Although production in Africa is ranked lowest compared to other continents, FAO statistics indicate that Irish potato production has increased from 8 to about 24 million metric tonnes from 1994 through 2011, attributed to agricultural technology's application [6]. The world productivity can rise by 140% if Irish potato farmers embrace the application of the available technology [7]. Entrepreneurs in sub-Saharan Africa have established that the uptake of agricultural technologies is key in increasing the yield of different crops, including the Irish potato.

In Kenya, the demand for Irish potato has risen in the past decade due to reduced production and increased urbanization. Irish potato is ranked as the second most consumed crop among town dwellers after rice [8]. Kenya has a potential yield of between 4 and 8 tonnes per hectare compared to a world potentiality of 30 tonnes per hectare [9]. Due to the high level of land fragmentation, Kenya's acreage of Irish potato farms has gradually reduced from 192,341 hectares in 2007

to about 109,614 hectares in 2017 [10]. The uptake of agricultural technologies can increase ease and efficiency at the farm level and act as a measure to overcome the decline in Irish potato production. Kenya has a high potential for potato production, which has remained underutilized for many years due to the lack of uptake of agricultural technologies in different parts of the country [8]. The Kenyan government has come up with structures in agricultural research that are geared toward enabling the agriculture sector to be responsive to low production.

Food and Agriculture Organization (FAO) has predicted that the population will increase to 9.7 billion people by 2050, and if so, world food production should rise by about 70% to accommodate the growth in the population [7]. Since the Irish potato is a major food crop, it is expected to contribute significantly to food security and income for smallholder farmers. Moreover, developing countries need to double their production to feed their population. Meeting the food demand will be a challenge that the farmers and other players in the agricultural sector will have to face head-on and devise measures to overcome [10]. For this reason, advancements in technology have made an extensive impact on the agricultural sector, more importantly in a reduction in the cost of production and an increase in yield and farm income. Through the reduction in the cost of production, farmers in the world have significantly increased profitability. New precision technologies in agriculture, such as improved fungicides, new cultivars, certified seeds, and dissemination of information through social media, could transform the potato subsector by increasing yield and optimal levels [11].

Financial factors have influenced the adoption of agricultural technologies in the past. Off-farm income, access to the credit facility, availability of subsidies, production risk, and cost of production were some of the variables associated with the adoption of agricultural technologies [12]. Farmers use off-farm capital as an investment plan for their farms to increase productivity, and the amount and availability influence the decision to adopt a given technology [13]. Credit access influences the decision of a farmer to adopt a given technology with ease [14]. Subsidies result in clouding in or out of the farmers in the places of supply of agricultural technologies, especially among financially unstable farmers [15].

Financial factors influence most agricultural decisions since the venture requires high investments in land, labor, technologies, and farm inputs. Risk-averse farmers are not likely to try new agricultural technologies, while risk-takers are expected to invest in promoting innovations [16]. The availability of financial resources to cater for production costs associated with labor and acquiring a given agricultural technology influence a farmer's decision to take up one. The off-farm income determines the technology to adopt [17]. There exists a contextual gap since the two studies were not carried out in Ol Kalou Sub County hence, this study will be carried out to fill the gap. Thus, it is essential to determine the influence of the availability of off-farm income, access to the credit facility, availability of subsidies, production risk, cost of production on the adoption of agricultural technologies, and farm income as financial factors.

Ol Kalou Sub County is a major Irish potato producer within Nyandarua County, but it does not meet its potential [9]. The area is suitable for Irish potato production due to its geographical location in the Aberdare Highlands receiving adequate rainfall [10]. Even though Ol Kalou is among the leading producers of Irish potato in Kenya, the majority of farmers have not adopted the agricultural technologies hence affecting their potentiality. On average the farmers in Ol Kalou produce 4-8 tonnes per hectare compared to the potentiality of about 30 tonnes per hectare produced in developed countries [18]. Studies in other countries have shown that off-farm capital, access to credit, availability of subsidies, production risk, and cost of production influence the adoption of agricultural technologies. However, in Ol Kalou Sub County, there is little or limited information on the influence of financial factors on the adoption of agricultural technologies. Therefore, the purpose of this study is to analyze the financial factors influencing the uptake of agricultural technologies.

2. METHODOLOGY

2.1 Study Area

The study was carried out in Kaimbaga, Rurii Karau, Kanjuire Ridge, and Mirangine wards of Ol Kalou Sub County in Nyandarua County in June and October 2022. The study area covered a total area of 384.9 km^2 and has a population of 75,262 (County Government of Nyandarua, 2018). The choice of Ol Kalou was influenced by the fact that the area had high Irish potato in the

past years, but by 2021, there was a reduction in the recent past [18]. Ol Kalou is located on the west slopes of the Aberdare Ranges, and it is one of the five sub-counties of Nyandarua County. Nyandarua County produced about 33% of the total Irish potato production in the country. Majority of the land in Ol Kalou Sub County is arable for Irish potato due to the fertile soils in the area.

2.2 Research Design

Descriptive cross sectional research design was used in this study. The design was used to gain accurate profile of situations and events on the Irish potato field. In addition, the design catered to the collection of quantitative and qualitative data on financial factors among the small-scare Irish potato farmers.

2.3 Population and Sample Size

The population of the study was 21,942 smallholder Irish potato farmers who owned at least five acres in Ol Kalou Sub-County. For one to qualify as respondent, they had to be owning below five acres of land. Additionally, the Irish potato farmer who had been in the production of the commodity continuously for the past five years was included. This helped to ensure that there were no new entrants in Irish potato production since they would have lacked adequate knowledge about the available agricultural technologies. The study used the Cochran [19] formula to compute the sample size of the smallholder Irish potato producers in Ol Kalou.

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

$$n = \frac{(1.96)(1.96)(0.5)(0.5)/0.5}{(0.05)(0.05)} = 385$$

where,
n= sample size of the smallholder potato farmers
Z = confidence level at 95%
e= margin of error
p=proportion of population
q=1-proportion of population (1- p)

The study assumed a 95% confidence level representing a 5% sampling error to obtain a sample size of 385 smallholder farmers of Irish potato in Ol Kalou Sub County (Table 1). The study used multiple stage sampling technique to select respondents from the entire population.

2.4 Data Analysis

The primary data collected was first checked and sorted for consistency and completeness before analysis. Checking and sorting were done with the aim of making sure all elements of the questionnaire were answered. The study used descriptive statistics like frequencies, percentages, means, and standard deviations to present and give summaries of data collected from smallholder Irish potato producers in Ol Kalou Sub County. The study also employed Pearson correlation analysis to establish any significant association between financial variables. Multinomial logistic regression was used to assess the influence of financial factors (off-farm income, access to credit, availability of subsidies, production risks, and production cost) on the adoption of agricultural technologies.

2.5 Multinormal Logistics Regression Model Specification

The financial factors influencing the rate of adoption of agricultural technologies were analyzed through multinomial logistic regression where the adoption rate of the dependent variable was categorized into three scores (ratio of disseminated technologies). Any farmer who adopted one or none of the four technologies (chemical fertilizer, certified seeds, fungicides, and use of farm machinery) was termed a low adopter, anyone with two was a medium adopter, while one with three and above was regarded as a high adopter (Table 2).

Table 1. Sample Size of Irish Potato Farmers

Ward	No. of Irish potato farmers	Proportionate constant	Sample size
Kaimbaga	5767	0.0175	101
Karau	3258	0.0175	57
Ruria	4543	0.0175	80
Kanjuire Ridge	3943	0.0175	69
Mirangine	4432	0.0175	78
Total	**21,942**		**385**

Table 2. Adoption scores and level of Irish Potato Farmers

Adoption Scores	Adoption Level
≤1	Low adopter
2	Medium adopter
≥3	High adopters

The multinomial logistic regression is used when the dependent variable can be expressed in more than two categories [20]. When there are *n* independent observations with *p*-explanatory variables, and the qualitative response variable *k* categories, then logit are consulted with one of the different categories taking the role of base level and the other logits are based on it [19]. The model in this study estimated the probability of each parameter on the dependent variable by expressing medium adopter as a base category of low adopters and high-adopters.

The study assumed that the Irish potato farmers are mutually exclusive, such that no one has the tendency to go below two or more levels. The study used the likelihood ratio chi-square statistics and Pearson chi-square statistics to provide a model checker in case the data is sparse. The multinomial response model specifies that in the case of N categories, the probability that a smallholder farmer is in a specific category is given by:

$$\mathrm{P}(Y=1)] = (\beta_0+\beta_1\mathrm{X}_1+\beta_2\mathrm{X}_2+\cdots+\beta_n\mathrm{X}_\mathrm{n}) \quad (2)$$

The alternative formula, directly specifying Prob (**x**), is:

$$\mathrm{Prob}(\boldsymbol{x}) = \frac{\exp(\beta_0+\beta_1\mathrm{X}_1+\beta_2\mathrm{X}_2+\cdots+\beta_n\mathrm{X}_\mathrm{n})}{\sum_{\mathrm{j}=1}^{2}\exp(\beta_0+\beta_1\mathrm{X}_1+\beta_2\mathrm{X}_2+\cdots+\beta_n\mathrm{X}_\mathrm{n})} \text{ for all j} = 1,2,3 \quad (3)$$

β_i refers to the effect of x_i on the log odds that Y=1 while controlling other x_j

where;

Prob $\mathrm{Y_i} = \mathrm{j}$ is the probability that Irish potato farmer *i* chooses agricultural technology j, *j* is equated to 1 for non-adopters, 2 when the level of adoption is low, and 3 in case levels of adoption is high. x_i is a vector of independent variables for smallholder Irish farmer i^{th} with a *j* level of adoption and coefficient β of the parameters (Table 2). Therefore, using a collective action, the non-adopters was the base category =1, while the probability of the medium adopters and high adopters at 2 and 3 would be;

$$\log\left(\frac{Prob_j(x_i)}{Prob_k(x_i)}\right) = \beta_{0i}+\beta_{1j}\mathrm{X}_{1\mathrm{i}}+\beta_{2j}\mathrm{X}_{2\mathrm{i}}+\cdots+\beta_{pj}\mathrm{X}_{\mathrm{pi}} \quad (4)$$

where j=1, 2, …, (k-1), i=1, 2…..n. Because all the Prob's add to unity, equation is reduced to

$$\mathrm{Prob}(\mathrm{Y_i}=\mathrm{j}) = \frac{\exp(\beta_{0i}+\beta_{1j}\mathrm{X}_{1\mathrm{i}}+\beta_{2j}\mathrm{X}_{2\mathrm{i}}+\cdots+\beta_{pj}\mathrm{X}_{\mathrm{pi}})}{1+\sum_{\mathrm{j}=1}^{2}\exp(\beta_{0i}+\beta_{1j}\mathrm{X}_{1\mathrm{i}}+\beta_{2j}\mathrm{X}_{2\mathrm{i}}+\cdots+\beta_{pj}\mathrm{X}_{\mathrm{pi}})} \text{ for all j} > 0. \quad (5)$$

Since the interpretation of MNL coefficients is not straight forward, the study computed marginal effects using Stata 17 Software to estimate the magnitude of the expected change in probability of adopting agricultural technology given a unit change in an independent variable. The study conducted a multicollinearity test to determine the variance inflation factor (VIF) and its independence from the irrelevant alternatives (IIA). The major assumption of MNL is independence from the irrelevant alternatives, which implies that the odds of adopting an alternative *i* relative to an alternative j is independent of the availability or the characteristics of the alternatives as opposed to *i* and *j*.

For j=1, 2, …, (k-1), the model variables are estimated by MNL estimate.

The IIA assumption necessitates that prior probabilities change precisely to retain original odds among all pairs of outcomes when a new alternative is available. For instance, the choice of one level of adoption alternative does not impact the relative probabilities of belonging to other levels or alternative. Gumbel (extreme value type I) distribution is assumed by MNL specification where the location parameter (mean) is zero and the error term, μ, is defined as the scale parameter. Additionally, the model assumed homogeneity of preferences and tastes across respondents. The MNL model was preferred since it allowed the analysis of adoption decisions across three dependent variable categories, making it possible to determine the adoption probabilities of different agricultural technologies. From the model, the study estimated that there would be either a positive or negative influence of the different explanatory variables used in the study on the explained variable (Table 4).

Table 3. Distribution of Explained and Explanatory Variables used in the Multinomial logit Model and Expected Signs Relative to the Adoption of Agricultural Technologies

Variable	Variable description	Measurement	Expected outcome
Adoption of AT	Adoption of AT coefficient (1= low, 2=medium,3=High)	Dummy	+/−
Off Farm Income	1=available, 0= unavailable	KES	+/−
Credit	Access to credit (1, accessible, 0, inaccessible)	KES	+/−
Accessibility of Subsides	Access to subsidies (1, accessible, 0 inaccessible)	KES	+/−
Production Risk	(1, present, 0 not present)	Dummy	+/−
Cost of production	Production cost	KES	+/−

Table 4. Correlation between Financial Factors Influencing Adoption of Agricultural Technologies

Variables		Off-farm	Access credit	Availability subsidies	Production risk	Production Cost
Off-farm	Pearson Correlation	1.00	0.23**	0.29**	-0.01	0.04
	Sig. (2-tailed)		0.00	0.00	0.84	0.49
Access credit	Pearson Correlation	0.23**	1.00	0.51**	0.25**	0.14**
	Sig. (2-tailed)	0.00		0.00	0.00	0.01
Availability subsidies	Pearson Correlation	0.29**	0.51**	1.00	0.21**	-0.20**
	Sig. (2-tailed)	0.00	0.00		0.00	0.00
Production risk	Pearson Correlation	-0.01	0.25**	0.21**	1.00	-0.01
	Sig. (2-tailed)	0.84	0.00	0.00		0.82
Production Cost	Pearson Correlation	0.04	0.14**	-0.20**	-0.01	1
	Sig. (2-tailed)	0.49	0.01	0.00	0.82	

*** Correlation is significant at the 0.05 level (2-tailed).*

3. RESULTS AND DISCUSSION

3.1 Correlation between Financial Factors Influencing Adoption of Agricultural Technologies

The study sought to establish the association between off-farm income, access to credit, availability of subsidies, production risk, and cost of production. The Pearson correlation findings of the study showed that the financial factors were correlated at 0.5% level of significance. The findings presented by this study showed off-farm income and access to credit had positive and significant correlation (0.23) with p-value of 0.00<0.05 (Table 4). The findings indicate that engagement exists between the off-farm activities and access to credit. In addition, the findings of this study imply that Irish potato farmers who were involved in off-farm activities tend to have access to credit. The availability of off-farm income implies that the farmers have a source of collateral for the credit given to them by financial institutions or non-formal groups. These findings are in consonance with those of Gupta *et al.* [22], who noted that off-farm income provides collateral for credits.

The Pearson correlation findings also revealed that there was a positive and significant correlation (0.29) with a p=0.00<0.05 between off-farm income and availability of subsidies (Table 4). This may imply that farmers involved in off-farm activities are more likely to benefit from subsidies. Also, the findings postulated that there was a strong positive and significant association (0.51) between access to credit and availability of subsidies with p=0.00<0.05 (Table 4). This may imply that the Irish potato farmers who have access to agricultural credit are more likely to take advantage of the availabilities of agricultural technologies. This study findings agrees with those of Omotilewa [15] who noted that availability of credit influences access to subsidies.

There was a weak and insignificant association (-0.01) with p=0.84>0.05 between production risks and costs of production. Moreover, the Pearson correlation findings indicated that there was a positive and significant association (0.25) with p=0.00<0.05 between access to credit and production risk. The findings suggest that Irish potato farmers who have access to credit may engage in riskier agricultural ventures that require high investment. These findings are supported by those of Jansuwan *et al.* [23], who noted that the level of riskier investment undertaken by a farmer is determined by capital availability. In addition, it was observed that access to credit and production cost had a positive and significant association (0.14) with a p-value of 0.01<0.05 (Table 4). These findings suggest that the Irish potato farmers who had access to agricultural credit had increased production costs, which may be attributed to interest earned from the loans. The findings of this study are in line with those of Siaw *et al.* [24], who reported that interest earned by agricultural credits increases production costs. However, the findings presented by this study are against those of Belachew *et al*. [25], who found that credit reduces the initial cost of production and allows farms to spread risk. The Pearson correlation findings also showed that there was a negative and significant association (-0.20) with a p-value of 0.00<0.05 between the availability of subsidies and production cost. The findings presented by this study imply that when Irish potato farmer access subsidies for inputs, their production cost are reduced.

3.2 Level of Agreement of the Financial Factors Influencing Adoption of Agricultural Technologies

The study sought to rank the influence of the availability of off-farm capital, access to credit, availability of subsidies, and cost of production on the adoption of agricultural technologies. The majority of respondents (50.91%) strongly agreed that off-farm capital facilitated the adoption of agricultural technologies. The findings also indicated that 34.29% agreed, 6.23% moderately agreed, 5.97% disagreed, and 2.60% of the respondents strongly disagreed that the availability of off-farm capital facilitated the adoption of Irish potato technologies (Figure. 1).

Furthermore, the findings of this study postulated that 49.35% of the respondents strongly agreed that access to credit influenced the adoption of agricultural technologies. The findings also indicated that 30.91%, 11,17% moderately agreed, 6.75% disagreed, and 1.82% strongly disagreed that access to credit influenced the adoption of agricultural technologies (Figure. 1). It was also established that the respondents strongly agreed that the availability of subsidies influenced the adoption of agricultural technologies. The findings of this study also revealed that 31.17% agreed, 5.71% moderately agreed, 8.05% disagreed, while 1.56% of

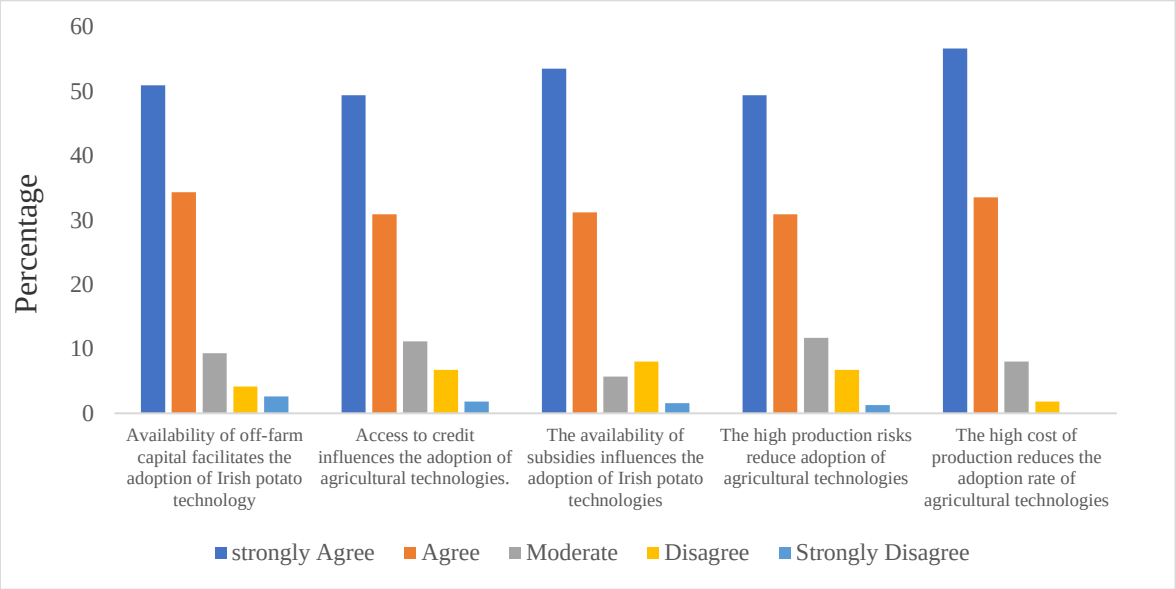

Fig. 1. Financial factors influencing adoption of agricultural technologies

respondents strongly disagreed that the availability of subsidies influenced the adoption of agricultural technologies (Figure. 1). Further, the study showed that 56.62%, 33.51%, 8.05%, and 1.82% strongly agreed, agreed, moderately agreed, and disagreed, respectively. The findings also revealed that no respondents (0.00%) strongly disagreed that the production cost influenced agricultural technologies adoption.

The study established that 84.20% of the respondents agreed that off-farm income, access to credit, availability of subsidies, production cost, and the cost of production influence the adoption of agricultural technologies in the Irish potato sector (Table 5). The majority (89.00%) of the Irish potato farmers established that the high cost of production associated with the cost of labor, cost of inputs, and fungicides were the main financial factors influencing the adoption of agricultural technologies. The findings also showed that 85.40%, 85.00%, 83.80%, and 78.20% of the respondents agreed that subsidies, availability of off-farm capital, access to credit, and production cost, respectively, influence the adoption of agricultural technologies (Table 5). The study suggests that Irish potato farmers should come up with other enterprises that will generate off-farm income to facilitate the adoption of agricultural technologies in the sector that will facilitate productivity improvement. Similar findings were reported by Baglan *et al*. [26] who noted that the cost associated with production and transaction influences the type of technology a farmer adopts.

3.3 Multinomial Logistic Regression for Financial Factors Influencing Adoption of Agricultural Technologies

This study tested for possible multicollinearity problems for the financial factors where the Variance Inflation Factor (VIF) showed that all the independent variables used had a VIF of below 5, hence indicating the absence of multicollinearity (Table 6). This study sought to model the influence of financial factors on the adoption of agricultural technologies using multinomial logistic regression (MLR) where the low adopters involving Irish potato farmers that had adopted one or none of the four agricultural technologies (use of chemicals, use of certified seeds, use of farm machinery, and fungicides) was used as the base category. To determine the relationship between financial factors and the adoption of agricultural technologies, the following hypothesis was formulated;

> *H_{01}: There is no statistically significant influence of access to financial factors on adopting agricultural technologies among Irish potato farmers in Ol Kalou Sub County.*

The chi-square value of -322.41 was obtained, which indicated that the likelihood ratio statistics were strongly significant (p=0.00), implying that the Multinomial Logistic Regression (MLR) model had strong explanatory power (Table 7). The chi-square value does not support the null hypothesis that there was no statistically significant influence of access to financial factors

on adopting agricultural technologies among Irish potato farmers. It was observed that the Pseudo-R square was 0.20, which suggested that the explanatory variables in the multinomial model explained 20.00% of the level of agricultural technology adoption by the Irish potato farmers, implying that the model well explained the variation in the dependent variable (Table 7). The multinomial logit model showed that the availability of off-farm income, access to credit, production risk, and availability of farm income significantly influenced the high adoption of agricultural technologies compared to the base category of low adoption. The model also indicated that the availability of farm subsidies had no significant effects, while production cost had a negative and significant influence on the high adoption of agricultural technologies compared to the base category of low adoption.

The model indicated that off-farm income had a positive and significant influence (p=0.00<0.01) on high adoption relative to low adoption of agricultural technologies among the Irish potato farmers in the Ol Kalou Sub County (Table 7). When comparing medium adopters to low adopters, this study's findings established that the availability of off-farm income increases the likelihood of medium adoption by a factor of 1.067, which indicates an increase of 6.7%. The MLR model's findings also established that an increase in Kenya Shillings KES 1 of off-farm income increases the likelihood of high adoption of agricultural technologies compared to low adoption by a factor of 1.133, which indicates an increase of 13.3% (Table 7). The marginal effect indicated that the probability of adopting more than three of the four agricultural technologies increased by 24.00% when a farmer increased off-farm income by one unit relative to the low adoption (Table 8). The findings suggest that off-farm income is critical in providing liquid capital to Irish potato farmers, improving their purchasing power for the different available technologies.

Similarly, the findings may imply that the off-farm income overcomes the credit barriers faced by smallholder farmers and offers the farmer disposable income to adopt more than two technologies. The findings may imply that farmers with off-farm income can withstand agricultural risks associated with uncertainties of production and bridge the gap by adopting the needed technology at the right time. The study's findings concur with those of Anang *et al*. [12], who stated that there was a positive and significant relationship between high adoption and expenditure on agricultural technologies for the farmers and the availability of off-farm income Tesema *et al*. [27] advanced similar findings that the availability of non-farm income influences the adoption of agricultural technologies positively because the availability shifts the cash barriers outwards, enabling the farmers to make a timely purchase of the innovations that they could not be in a position to acquire using the farm income. Similar findings were advanced by Zheng *et al*. [28], who noted that off-farm income and farm mechanization expenditure are correlated, and non-farm income positively influences mechanization services. The findings also contradict with those of Jansuwan *et al*. [23] who reported that an increase in off farm income undermines the uptake of agricultural technologies by reducing the household labour allocated to the agricultural sector.

Table 5. Mean Agreement on a scale of 1-5 of Financial Factors Influencing Adoption of Agricultural Technologies in the Irish Potato Subsector

Factors	Mean Agreement on a Likert scale of 1-5 points	Percentage	Std. Deviation
Availability of off-farm capital facilitates the adoption of Irish potato technology	4.25	85.00	0.99
Access to credit influences the adoption of agricultural technologies	4.19	83.80	1.00
The availability of subsidies influences the adoption of Irish potato technologies	4.27	85.40	0.99
The high production risks reduce adoption of agricultural technologies	3.91	78.20	0.85
The high cost of production reduces the adoption rate of agricultural technologies	4.45	89.00	0.72
Total Mean	**4.21**	**84.20**	

Table 6. Variance Inflation Factor Financial Factors

Financial Factors Variance Inflation Factor		
Variable	**VIF**	**1/VIF**
Availability of Off-farm Income	2.12	0.47
Production Cost	2.00	0.50
Access to Credit	1.71	0.59
Production Risk	1.24	0.81
Availability of Subsidies	1.05	0.95
Mean VIF	1.62	

Table 7. Coefficients of multinomial logistic regression model financial factors on adoption of agricultural technologies

Reference Category:	**Medium Adopter**				**High Adopter**			
Low Adopter	**Coef**	**rrr**	**Std Error**	**p-value**	**Coef**	**rrr**	**Std Error**	**p-value**
Availability of Off-Farm Income	0.31	1.067	0. 42	0.51	1.11***	1.133	0.36	0.00
Access to Credit	0.49	1.122	0.43	0.19	1.36*	1.132	0.59	0.01
Availability of Subsidies	0.16	0.994	0.41	0.89	-0.36	0.931	0. 37	0.29
Production Risk	0.23	1.133	0. 39	0.58	1.42***	1.135	0.46	0.00
Production Cost	-2.1***	0.893	0.24	0.00	-0.19	0.811	0.44	0.50
No of observations								385
Prob>Chi2								0.00
Pseudo R^2								0.20
Log-likelihood								-322.41

*Note: *** significant at 1% level, ** significant at 5% level, *significant at 10% level*

Table 8. Conditional marginal effects of multinomial logistic model for the financial factors

Reference Category:	**Medium Adoption**			**High Adoption**		
Medium Adoption	**dy/dx**	**Standard Error**	**p-value**	**dy/dx**	**Standard Error**	**p-value**
Off Farm Income	-0.16	0.15	0.27	0.24**	0.11	0.01
Access to Credit	-0.02	0.01	0.06	0.04***	0.03	0.00
Availability of Subsidies	0.09	0.11	0.50	-0.06	0.04	0.17
Production Risk	-0.04	0.07	0.40	0.21***	0.07	0.00
Production Cost	-0.05***	0.09	0.00	0.46	0.06	0.21

*Note: *** significant at 1% level, ** significant at 5% level, *significant at 10% level*

Access to agricultural credit had a positive and significant influence (p=0.01<0.05) on the high adoption of Irish potato technologies relative to low adoption (Table 7). The MLR model established that when comparing medium adoption to low adoption, an increase in access to credit by 1 KES increased the likelihood of medium adoption by a factor of 1.122, which is 12.2%. The model also showed that an increase in credit by 1 KES increased the likelihood of high adoption compared to low adoption by a factor of 1.132, indicating an increase of 13.2% (Table 7). The marginal effect showed that the probability of adopting any of the three agricultural technologies increased by 4.00% for every increase in KES 1 of credit compared to the uptake of one or none of the technologies (Table 8). During the study, it was observed that credit was accessible to the majority of the Irish potato farmers in the Ol Kalou Sub County. The availability and accessibility of credit may imply that Irish potato farmers have a way to overcome the financial obstacles associated with acquiring technologies that require high investment.

The findings may imply that access to credit enabled the relaxation of the liquidity barriers and boosted the farmers' capacity to bear risks associated with the failure of one agricultural technology. In addition, the findings may imply that access to credit is essential in increasing Irish potato farmers' economic opportunities, and it is an essential pathway that farmers can use to acquire complementary technologies. The findings of the study are in agreement with those of Aurangozeb [13], who reported that access to credit is an essential factor in the adoption of agricultural technologies since it offers the farmer the capacity to procure the disseminated innovations. The study's findings are in consonance with Siaw *et al*. [24], who found that access to credit positively influences the adoption of agricultural technologies since the loan allows the farmers to have financial resources that can be used to invest in new innovations.

Similarly, this study's findings align with those of Zegeye *et al*. [27], who reported that access to credit increases the farmer's adoption decision of innovation as it solves the financial constraint and serves as the source of finance for low and medium households to acquire new technology. Furthermore, Hunecke *et al*. [14] reported similar findings that access to credit influenced the adoption of agricultural technologies since the option to borrow helps the farmers eliminate risk-reducing and inefficient income innovations and concentrate on profitable earning technologies. The findings of this study are supported by Siaw *et al*. [22], who found that limited access to credit facilities diminished the chances of uptake of agricultural innovations. However, the study's findings contradict those of Belachew *et al*. [25], who noted that despite the credit availability, farmers used the loan for non-farm activities other than channeling the funds towards adopting agricultural technologies.

The availability of subsidies had no significant influence (p=0.89, 0.29>0.1) on the adoption of agricultural technologies for medium and high adopters, respectively, relative to low (Tables 7 and 8). When comparing the medium adoption and low adoption, the findings of the MLR model showed that an increase in a unit change of availability of subsidies reduces the likelihood of medium adoption by a factor of 0.994, implying a 6% decline. In addition, the MLR model showed that a unit change in the availability of subsidies reduces the likelihood of high adoption by a factor of 0.931, implying a 6.9% decline in high adoption of agricultural technologies (Table 8). This means that most of the farmers in the Ol Kalou Sub County had only adopted two of any of the four in their production of Irish potato. The findings implied that despite the availability of subsidies from both County and National governments, they did influence the adoption of agricultural technologies.

The findings may also indicate that the subsidies offered to the farmers were not timely, despite efforts by both the County and National; hence, it delayed the uptake of the technologies. For instance, farmers stated that subsidized fertilizers and certified seeds were offered months later after planting season. The study also implies that the difficulty in accessing government measures like subsidies did not affect the adoption rate of the four technologies. The study observed that subsidies do not influence the adoption of agricultural technologies since most of them are not demand-driven and do not consider the needs of farmers. The findings of this study were in agreement with Belachew *et al*. [25], who noted that subsidies do not influence the adoption of agricultural technologies. However, the findings of this study are against those reported by Koppmail *et al*. [30], who revealed that subsidies reduce the cost of production, hence encouraging the farmers to uptake the innovations.

Further, the findings of this study contradict those reported by Hong *et al*. [29], who noted that subsidies influence the adoption of agricultural technologies as they increase affordability. The findings are against those of Belachew *et al*. [25], who reported a strong correlation between the number of subsidies and the probability of adopting agricultural technologies. Moreover, the study's findings are against Omotilewa *et al*. [15], who established that subsidies increase the likelihood of farmers adopting new technologies and that households with subsidies could buy technology at commercial prices compared to households that did not have a subsidy.

The model's findings indicated that production risks had a positive and significant influence (p=0.00<0.01) on the high adoption of agricultural technologies relative to low adoption (Table 7). In the MLR model, when comparing medium and low adopters, the findings showed that a unit increase in measures of reducing production risk by one unit increases the likelihood of medium adoption by a factor of 1.133, indicating a 13.3% increase in medium adoption. The model also showed that when comparing high adoption to low adoption, an increase in measures to reduce production risk by one unit increases the likelihood of high adoption by a factor of 1.135, indicating an increase in high adoption by 13.5% (Table 7). The marginal effect showed that the probability of adopting more than three of the four agricultural technologies increased by 21.00% when a farmer increased insurance coverage by one unit (Table 8). This means that the Irish potato farmers with insurance coverage against their Irish potato were likely to adopt more than three of the four agricultural technologies. The cover was mainly for the large-scale farmers who adopted farm machinery. This suggests that smallholder farmers with other forms of technologies may lack savings to fall back on them, hence preferring less costly innovations.

The findings are similar to those of Murthy *et al*. [32], who noted that the availability of risk coping mechanisms, particularly insurance cover, influences the adoption of agricultural technologies, especially when they are new and the proper use and benefits accrued are not well known to farmers. On the contrary, the findings of the study are against those of Rusteika [33], who stated that the production risk does not influence the decision to adopt an agricultural technology since adoption is a continuous problem, and when it comes to divisible technologies, the farmer can adopt small amounts at a time thus learning before rolling it out. Further, the findings contradict those of Harrison [34], who revealed that risk preferences and limited liability among the farmers who have less to lose in case of an eventuality lead to high adoption.

The multinomial logistic regression model findings indicated that production cost had a negative and significant influence (p=0.00<0.01) on high adoption relative to low adopters of agricultural technologies among the Irish potato farmers in the Ol Kalou Sub County (Table 7). The model indicated that when comparing medium and low adoption, an increase in the cost of production by KES 1 reduces the likelihood of medium adoption by a factor of 0.893, indicating a decline of adoption by 10.7%. The MLR model also showed that comparing high adopters to low adopters, an increase in the cost of production by 1 KES reduces high adoption by a factor of 0.811, implying an 18.9% decline in high adoption (Table 7). The marginal effect analysis indicated that the probability of high adoption of the four agricultural technologies decreased by 5.00% when the cost of production increased by KES 1 (Table 8). The findings showed that the cost of inputs, labor, and other transaction costs that a farmer incurred reduced the ability to uptake agricultural technologies.

The findings also may imply that the net gain that Irish potato farmer delivers from the farm is not the major determinant of adoption, but the overall cost of using the technology influences when and why one uptake a given innovation. Similarly, the model's findings show that the production cost significantly reduces the adoption of agricultural technologies among small-scale farmers. These findings concur with those of Siaw *et al*. [24], who stated that an increase in the cost of labor, which is one of the factors of production, reduces the adoption of technology. Further, Baglan *et al*. [26] revealed that the costs of inputs, labor, and other transactional expenses determine the intensity of uptake of agricultural technologies, and the higher the cost, the lower the level of adoption, especially for poor farmers. Based on the findings of this study, the cost of initial purchase and labor influence the cost of obtaining agricultural technologies. Similar findings were advanced by Tesema *et al*. [27], who postulated that the adoption of agricultural technologies is dependent on the cost of production, ranging from the cost of purchase, maintenance, and labor.

Further, the study's findings are in agreement with Zheng *et al*. [28], who found that the cost of production, especially the initial cost of the technology, influences the smallholder farmers' ability to acquire new technology. The findings of the study are in agreement with Gupta *et al*. [22], who found that the cost of production is a major factor that influences the adoption of innovations in agriculture, and the lack of funds to fund the purchase, labor, and maintenance makes developing countries have a low level of uptake of the available technologies. In contrast, Zegeye *et al*. [29] study established that high production cost facilitates farmers to adopt new technologies that are essential in reducing labor employed in a particular farm.

4. CONCLUSION

The availability of off-farm income is essential in influencing the adoption of agricultural technologies. Farmers with a large base of off-farm income had a high adoption rate of agricultural technologies. The majority of the farmers have diverse sources of off-farm income that are used to make investments in agricultural production. Credit facilities play a role in bridging the gap of the unavailability of capital that farmers use to uptake agricultural technologies. Many institutions were willing to offer the farmer credit. Different types of subsidies were available for the Irish potato farmers in Ol'Kalou. In addition, though many Irish potato farmers do not have insurance to mitigate risks, the strategy plays a significant role in adopting agricultural technologies. The adoption of agricultural technologies is also influenced by the cost of production, where if it is labor-intensive, farmers become resistant to it. Farmers need to invest in farm income to the adoption of technologies that are essential in enhancing productivity. The study recommended that the government should develop policies and regulations such as diversification of income, grants that reduce production costs, credit incentives, and crop insurance.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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