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FACTORS INFLUENCING NEW TECHNOLOGY ADOPTION BEHAVIORS OF RICE FARMERS: BINARY LOGISTIC REGRESSION MODEL APPROACH

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ABSTRACT: *The purpose of this study is to identify factors affecting the behavior of rice farmers in choosing new technology application. The study employed Binary Logistic Regression model on survey data of 455 rice farming households in the Mekong Delta, Vietnam. The results show that influencing factors include: Human capital, Physical capital, Social capital, Perceived risk, Uncertainty and Market access.*

KEYWORDS*:* choice behavior; rice farmers; technology; binary logistic regression model; Mekong Delta, Vietnam.

INTRODUCTION

In recent years, there have been many studies on the effectiveness of applying new technology to rice production. However, not many studies have paid enough attention to factors affecting the farmer's behavior in the application of new technology. This is also a challenging issue for researchers and agricultural managers in the context of Vietnam integrating into the world and improving production efficiency associated with sustainable development. This study focuses on (i) Determining factors affecting the decision to apply new technologies in rice production; (ii) Build a Binary Logistic Regression model on this relationship; (iii) Policy implications from research results. The study conducted a survey of 455 rice farming households in the Mekong Delta, Vietnam to create a practical basis for the measurement model. The Mekong River Delta is a large land, accounting for 12% of the area, 19% of the country's population, a dense network of rivers, springs and canals; has advantages in developing agriculture, food industry, tourism, renewable energy; is the largest agricultural production center of Vietnam: contributing 50% of rice production, 65% of aquaculture production, and 70% of fruits of the country; 95% of exported rice and 60% of exported fish; has a convenient position in trade with ASEAN countries and the Mekong Sub-region (Government, 2017).

THEORETICAL OVERVIEW

Foundation theory

Theory of reasoned action:

The theory of reasoned action (TRA) of Ajzen & Fishbein (1980) argues that behavioral intentions are determined by individual attitudes, while individual attitudes are influenced by that individua's standards or expectation (subjective norm). Attitude and subjective norms need to be measured in

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the study of behavioral intentions. A model is used to predict how individuals will behave based on their pre-existing attitudes and behavioral intentions. The high correlation between behavioral intention and actual behavior has been confirmed in many studies (Sheppard *et al*., 1998). However, there is still much debate about the cohesive relationship between behavioral intention and actual behavior, because under certain circumstances, behavioral intention does not always lead to actual behavior.

Theory of planned behavior*:*

Theory of Planned Behavior (TPB) of Ajzen (1991) suggests that the intention to perform a behavior will be influenced by three factors such as attitude towards the behavior, subjective criteria and awareness of behavioral control. Thus, the TPB was developed from the theory of rational action and overcomes the limitation that human behavior is completely controlled. There are three basic determinants in this theory: (i) The personal factor is the individual's attitude towards the behavior regarding the positive or negative awareness of performing the behavior; (ii) Regarding an individual's intention to social pressure, because it copes with the perception of pressure or subjective compulsion, it is called subjective norm; and (iii) Finally, the determinant of self-efficacy or the ability to perform a behavior, called behavioral cognitive control. The TPB suggests the importance of attitude towards behavior, subjective norm and behavioral cognitive control leading to the formation of behavioral intention.

Theory of technology dissemination*:*

Rogers (1995) considers the influence of two factors: compatibility and advantages on the adoption of a new technology. This theory explains how ideas and technologies are spread and accepted through five stages: awareness stage, persuasion stage, decision-making stage, implementation stage and validation stage. The factors that influence the behavior of accepting technology selection include: (i) related benefits, (ii) adaptability, (iii) ease of access, (iv) ease of experimentation, and (v) ease of observation. The theory suggests that the extension system, when conducting the transfer of new technologies in agriculture, should pay attention to the decision-making process of farmers when choosing new technologies.

Technology acceptance theory*:*

Davis (1985) argues for a causal relationship between the usefulness and attitudes of users when approaching a new technology. User attitudes are influenced by perceived usefulness and perceived ease of use is the degree to which users believe that using it is effortless when put into practice. According to this theory, farmers will choose to apply sustainable agricultural production methods if they (i) feel positive about the benefits that these measures bring and (ii) have the ability to apply these measures into production practice without encountering too many barriers in terms of knowledge degree and resources.

Unified theory of technology acceptance and use*:*

According to Venkatesh *et al*. (2003), farmers choose to apply sustainable agricultural production methods influenced by factors (i) perceived benefits that the measures bring, (ii) the degree of ease of application compared to capacity, (iii) the influence of society on the role of agricultural

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extension activities, (iv) the availability of resources such as human capital, physical capital, accessibility other resources, and (v) demographic characteristics of the household.
The above theories are relevant to this study, where it is important to explain the source of behavioral intention and actual behavior, the role of extension in influencing behavior, and perceived usefulness in influencing behavior decisions to apply new technology and technical solutions.

New technology in rice production and influencing factors

New technology:
Since the beginning of 2000, in order to help rice farmers to further improve the efficiency of rice cultivation in order to increase their income and protect the environment, in association with sustainable agricultural development, the Vietnam Ministry of Agriculture and Rural Development popularizes new technologies: "3 down, 3 increase" and "1 must, 5 decrease".

Technology "3 down, 3 increase":
Due to the traditional practice, farmers conduct sowing (high seed density per ha) is not necessary, reasonable seed density will reduce the number of varieties but the yield will not decrease; Fertilization techniques of Vietnamese farmers often suffer from excess nitrogen (absolute value and relative value of nitrogen fertilizer in relation to phosphorus and potassium). A reasonable combination with reduced nitrogen fertilizer and balanced organic fertilizers, can reduce the amount of inorganic fertilizers; Excessive use of pesticides has caused serious harm to production, environment and public health. To achieve efficiency in the use of pesticides, farmers should have priority in choosing to use biological methods, biological pesticides. In case of force majeure, it is necessary to use chemical drugs, then use new generation drugs, which are less toxic, only need to be used in very small amounts but with high efficiency, so the amount of pesticides will be reduced. Three increases: increase productivity, increase quality, and increase profits (Pham Van Du, 2008).

Technology "1 must, 5 decrease":
This technology is an extension of the "3 down, 3 increase" technology. One must be to use good seeds and certified varieties, while five other ones must include reducing irrigation water, reducing post-harvest losses and plus the previous three reductions "3 decrease, 3 increase" is a decrease in the amount of seed sown; reduce nitrogen fertilizers and reduce the use of pesticides (Plant Protection Department, 2011).

Factors affecting the behavior of choosing new technology applications:
Research on rural areas in Tanzania (Berresaw *et al*., 2013) shows that the main factors affecting farmers' decision to adopt new technologies include: extension services, social capital, area of productive agricultural production land, and market access. A study of smallholder farmers in Zimbabwe found that factors influencing farmers' decision to adopt new technologies: education, age of household head, size of land area, income and access to information, and markets (Murendo *et al*., 2016). On the other hand, studies in Kenya and Tanzania (Kamau *et al*., 2014; Kassie *et al*., 2015) found that age may be related to short-term planning and more risk aversion. Therefore, the

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effect of age on technology adoption is not clear. The Ethiopian study by Mutyasira *et al*. (2018) also found that access to formal credit and non-agricultural income influence new technology adoption. The study of farm households in Hoduras and farms in Georgia also discovered a new element: perceived usefulness as a result of the neighborhood's application of new technology and participation in community activities (Meike & Camilla, 2014; Munasib & Jordan, 2011). Research by Oduniyi & Tekana (2021) on maize farmers in South Africa shows that the demographic score of the farmer household is an important factor affecting the decision to choose new technology.

From the 2010s up to now, a synthesis of empirical studies shows that there are five groups of factors affecting farmers' decision to apply new technology: Human capital; Physical capital; Social capital; Perception of risk/ uncertainty; and Market access. The study conducted a survey of 10 management experts in the agricultural industry in Can Tho City, Vietnam to identify specific groups of factors to suit the characteristics of Vietnam's agriculture.

Human capital: including Gender; Age; and Education level of the household head.
Physical capital: including Agricultural land area; Access to credit and other agricultural income of households.
Social capital: household heads participate in farmer associations, farmer unions, agricultural extension clubs, and participation level with agricultural extension staff.
Perception of risk/ uncertainty: household head has a sense of usefulness before adopting new technologies.
Market access: represents the distance from your home to the local markets.
Based on empirical studies, the study proposes the following hypothesis:
H1: The gender of the household head affects positively the decision to apply new technology;
H2: The age of the household head affects positively the decision to apply new technology;
H3: The educational level of the household head affects positively the decision to apply new technology;
H4: The agricultural land area of the household affects positively the decision to apply new technology;
H5: A household's ability to access credit affects positively the decision to apply new technology;
H6: Households with non-agricultural incomes influence positively the decision to apply new technology;
H7: Householders' participation in farmer associations, farmer unions, extension clubs affects positively the decision to apply new technology;
H8: Participation level with agricultural extension staff affects positively the decision to apply new technology;
H9: Household head feels it is useful to apply new technology; and
H10: Distance from home to local markets affects positively decisions to adopt new technology.

RESEARCH MODEL

Theoretical reviews and empirical studies are needed for further research to extend the theory, provide more empirical evidence and theoretical policy implications related to multidimensional

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poverty reduction. Previous studies highlight insights into the impact of five groups of factors on new technology adoption decisions and measure relationships using different, independent quantitative models such as statistical tests, linear regression or separate regression models, but do not provide an adequate basis for a comprehensive analytical framework on factors for decision to adopt new technology. Therefore, the aim of this study was to extend the findings from previous studies and integrate analysis of the relationships in the Binary Logistic Regression model. This study selected the research model for the Mekong Delta as follows:

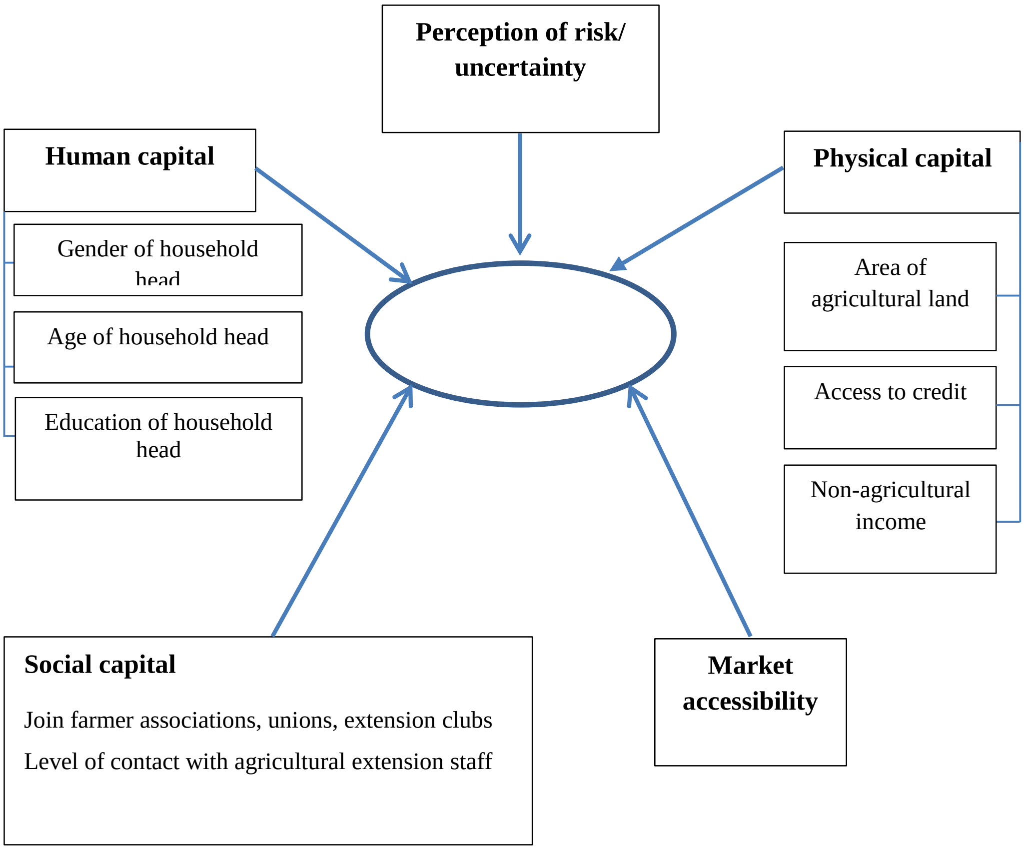

Fig. 3: Research model

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Table 1: Definitions of variables and expectations

No	Variables	CODE	Units	Expectation
I	**Dependent variables**			
	New technology application selection	Y	Yes = 1; No = 0	
II	**Independent variables**			
1	**Human capital**			
	Gender of household head	X1	Male = 1; Female = 0	+
	Age of household head	X2	Number of years	-
	Education	X3	Years of schooling (1–12)	+
2	**Physical capital**			
	Area of agricultural land	X4	1000 m2	+
	Access to credit	X5	Yes = 1; No = 0	+
	Non-agricultural income	X6	Yes = 1; No = 0	+
3	**Social capital**			
	Join farmer associations, farmer unions, extension clubs	X7	Yes = 1; No = 0	+
	Participation level with agricultural extension staff	X8	Number of contact times with extension in a crop	
5	**Perception of risk/ uncertainty**			
	Useful feeling	X9	Yes = 1; No = 0	+
6	**Market accessibility**			
	Distance to the nearest central market	X10	Km	-

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Note: The age of household head (*) has a negative sign because in terms of applying new technology, the younger household head has higher education and access to information than the older household head.

RESEARCH DESIGN

Quantitative model

Form of the research model: Y = f(X1, X2,…,X10)

General form of the linear regression model:

$$Y = B_0 + \sum_{i=1}^{n} B_i X_i + u$$

Xi: Independent variables; Y: Dependent variable; u: Residuals.

According to Howitt & Cramer (2011), when the dependent variable is a dummy variable (Dummy variable, Y = 1; Y = 0), the appropriate model is the Binary Logistic Regression model. In this study, the dependent variable is a dummy variable, the Binary Logistic Regression model is applied in this study.

Thus, the appropriate model is the Binary Logistic Regression:

$$Ln\left[\frac{P(Y=1)}{P(Y=0)}\right] = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + .. + B_{10}X_{10} \qquad (1)$$

Of which:

P(Y=1) = P_0: The probability of households selects new technology application

P(Y = 0) = 1- P_0: The probability of households did not select new technology application.

Xi: Independent variables (i: from 1 to 10); Ln: Log of base e (e = 2,714).

Coefficient Odds (O_0):

$$O_0 = \frac{P_0}{1-P_0} = \frac{P(\text{multidimensional poor households})}{P(\text{multidimensional non-poor households})} \qquad \text{(Coefficient Odds)}$$

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Substitute O_0 into the equation (1):

$$LnO_0 = B_0 + B_1 X_1 + .. + B_{10} X_{10} \qquad (2)$$

The Odds log is a linear function with the independent variables Xi (Cox, 1958).

Equation (2) has the form of a Logit function, estimating the regression coefficients by the Maximum Likelihood (ML) method.

Data collection and processing

The study conducted a survey of 455 observations in 7 communes of 7 provinces An Giang, Dong Thap, Long An, Kien Giang, Tien Giang, Can Tho, and Soc Trang in the Mekong Delta to represent the agro-ecological conditions, including: alkaline soil (Long Xuyen quadrangle, west of Hau River, Dong Thap Muoi), fresh alluvial area of Tien river (Cai Lay, Tien Giang), and less alluvial area (Chau Thanh, Long An). In each locality, the study interviewed the norm of 65 rice farmers based on the contact support of agricultural extension officers and farmers' associations in the locality.

All respondents were identified as heads of households, with convenient stratified sampling, conducted from March 2018 to March 2019. After data processing, 420 observations were made. ensure suitability and use for data analysis. All data processing was carried out based on SPSS version 21.0 software. Data were collected through direct interviews with detailed questionnaires to test the research model and hypotheses.

RESULT

Describe the characteristics of the survey object

Gender and decision on new technology application: In 420 surveyed households, male heads of the households account for the majority (83%). Female heads of the household do not apply new technology very high (76%) while male heads have only 24%.

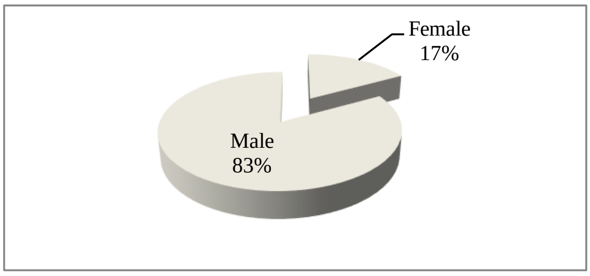

Fig. 2: Gender of head of household (%)

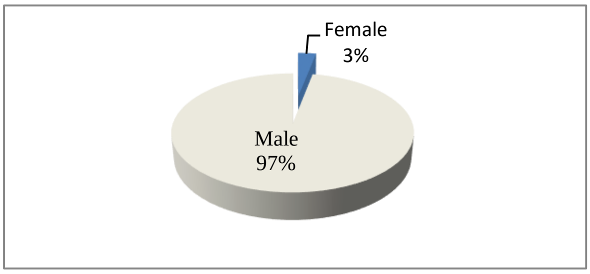

Fig. 3: Gender of head of household without new technology (%)

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Table 2: The mean value of the variables

	Mean	Std. Deviation
Age of household head	41	11.033
Years of schooling (1–12)	8	3.249
Area of agricultural land	2,830	1.088
Participation level with agricultural extension staff	2	1.181
Distance to the nearest central market	4,630	2.064

Table 2 shows that the average age of the household head is 41; Education level: 8th grade; Agricultural land area: 2830 m2; Number of times of contact with agricultural extension officers: 2 per production crop; Distance from home to the nearest market: 4,63 Km.

Borrowing and deciding to apply new technology: For households applying new technology, 85% of households borrow from formal credit institutions.

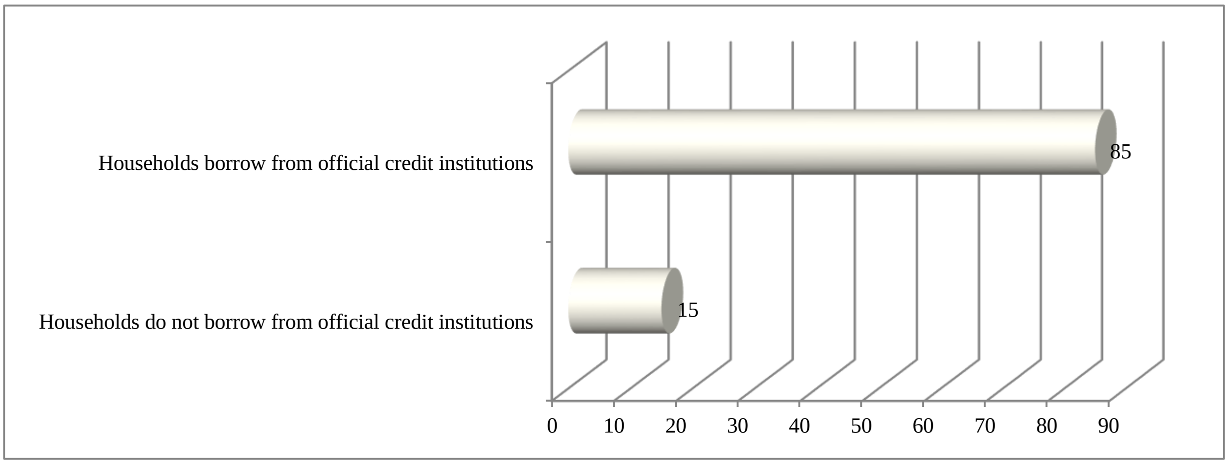

Fig. 4: Loan status at formal credit institutions (%)

Join farmer associations, farmer unions, extension clubs: For households applying new technology, 98% of households participate.

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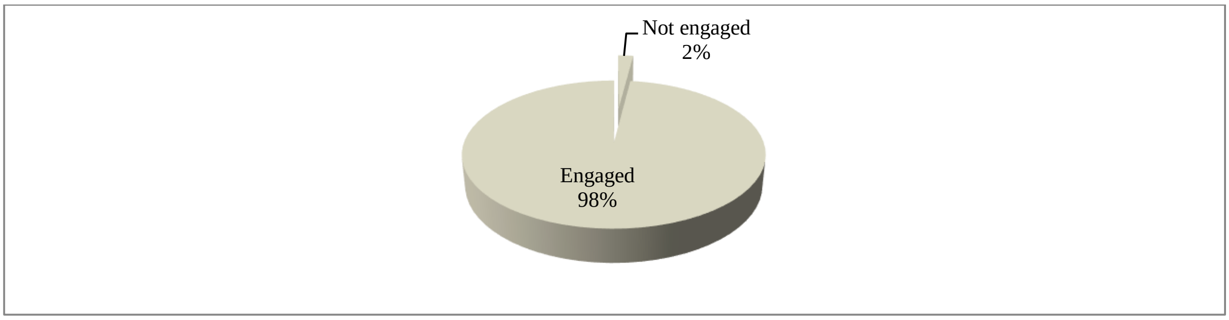

Fig. 5: Status of joining farmer associations (%)

Regression results

Table 3. Variables in the equation

Variables	B	S.E.	Wald	Sig.	Exp(B)	95% C.I. for EXP(B)	
						Lower	Upper
X1	1.472	1.073	1.883	0.170	4.358	0.532	35.683
X2	-0.070	0.031	5.034	0.025	0.933	0.878	0.991
X3	0.786	0.180	19.109	0.000	2.194	1.543	3.121
X4	1.431	0.427	11.203	0.001	4.182	1.809	9.666
X5	2.326	0.783	8.819	0.003	10.237	2.205	47.524
X6	1.628	0.798	4.160	0.041	5.094	1.066	24.349
X7	2.666	1.036	6.618	0.010	14.383	1.887	109.652
X8	1.914	0.469	16.618	0.000	6.779	2.701	17.013
X9	2.156	0.898	5.762	0.016	8.637	1.485	50.227
X10	-0.535	0.213	6.322	0.012	0.586	0.386	0.889
Constant	-14.535	3.145	21.355	0.000	0.000		
R^2 Nagelkerke	0.939						
Omnibus Tests	0.000						

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Wald's test shows that there is a variable X1 with Sig. > 0.05; The remaining variables all have Sig. ≤ 0.05. The sign of the regression coefficients is consistent with the hypothesis. R2 Nagelkerke = 0.939, so 93.9% of the change in the dependent variable is explained by the independent variables of the model. Omnibus testing with Sig. ≤ 0.05, overall, the independent variables are linearly correlated with the dependent variable. Thus, the independent variables that have a statistically significant impact on the Y variable "Decision to apply new technology" include: X2, X3, X4, X5, X6, X7, X8, X9, and X10.

Table 4: Level of impact of factors affecting the decision to apply new technology

				Initial probability $P_0 = 10\%$	
	B	**eB**	**Pi (%)**	**Probability Change (Absolute Value)**	**Position**
X2	-0.070	0.933	9.39	-0.6	**9**
X3	0.786	2.194	19.60	9.6	7
X4	1.431	4.182	31.73	21.7	5
X5	2.326	10.237	53.22	43.2	2
X6	1.628	5.094	36.14	26.1	6
X7	2.666	14.383	61.51	51.5	**1**
X8	1.914	6.779	42.96	33.0	4
X9	2.156	8.637	48.97	39.0	3
X10	-0.535	0.586	6.11	-3.9	8

Note: How to calculate *Pi* in Appendix.

In Table 4, the order of impact on "Decision to apply new technology" is strongest to lowest: X7 (Age of household heads); X5 (Access to credit); X9 (Feel useful); X8 (Feel useful); X4

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(Agricultural land area); X6 (Other income from agriculture); X3 (Education level); and X10 (Distance from home to the nearest market); X2 (Age of household heads).

Table 4: Hypothetical results

Hypothesis	Impact			Estimate	S.E.	Sig.	Decision
H1	Y	<---	X1	1.472	1.073	0.17	Reject
H2	Y	<---	X2	-0.070	0.031	0.025	Fit
H3	Y	<---	X3	0.786	0.180	0.00	Fit
H4	Y	<---	X4	1.431	0.427	0.001	Fit
H5	Y	<---	X5	2.326	0.783	0.003	Fit
H6	Y	<---	X6	1.628	0.798	0.041	Fit
H7	Y	<---	X7	2.666	1.036	0.010	Fit
H8	Y	<---	X8	1.914	0.469	0.00	Fit
H9	Y	<---	X9	2.156	0.898	0.016	Fit
H10	Y	<---	X10	-0.535	0.213	0.012	Fit

The results presented in Table 4 show that: Accept H1, remains hypotheses are accepted at a confidence level of over 95%.

Predicted scenario for a change of new technology application

The model's regression equation:

$$Y = -12.949 - 0.079X2 + 0.756X3 + 1.253X4 + 2.216X5 + 1.854X6 + 2.881X7 + 1.984X8 + 1.973X9 - 0.464X10 \quad (3)$$

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Table 5: Statistical value of variables and scenarios

	Minimum	**Maximum**	**Scenario 1**	**Scenario 2**
X2	20	63	63	20
X3	1	12	1	12
X4	2	5	2	5
X5	0	1	0	1
X6	0	1	0	1
X7	0	1	0	1
X8	0	4	0	4
X9	0	1	0	1
X10	1	13	13	1

Scenario 1 (SCE1): *X*i are independent variables with the lowest values according to the theoretical model expectations.

Scenario 2 (SCE2): Xi are independent variables with the highest values according to theoretical model expectations.

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Table 6: Forecast with scenario of impacting factors

No	Variables	Regression coefficient (B)	Values of variables	
			SCE 1	**SCE 2**
2	X2	-0.079	20	63
3	X3	0.756	1	12
4	X4	1.253	2	5
5	X5	2.261	0	1
6	X6	1.854	0	1
7	X7	2.881	0	1
8	X8	1.984	0	4
9	X9	1.973	0	1
10	X10	-0.464	1	13
12	Constant	-12.949		
	LogOdds		-11.731	8.521
	$e^{logOdds}$		0.00000804	5019.070318
	$1+e^{logOdds}$		1.000008	5020.070318
	P(Y/Xi): Probability that Y = 1 occurs is when the independent variable X has a specific value Xi (%).		0	1

Note: How to calculate E(Y/Xi) see Appendix.

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Substitute the **SCE1** values into equation (3), resulting in LogOdds. If the household has the following conditions, this household has a probability of "Applying new technology" of 0%.

X2 = 63 (Age of household heads); X3=1 (Education level); X4=2 (Agricultural land area); X5=0 (Access to credit); X6=0 (Other income from agriculture); X7=0 (Age of household heads); X8=0 (number of contact times with extension in one crop); X9 = 0 (Feel useful); and X10 = 9 (Distance from the house to the nearest market).

Scenario 2 (**SCE1**): *X*i are independent variables with best values.

Substitute the **SCE2** values into equation (3), resulting in LogOdds. If the household has the following conditions, this household has a 100% probability of "Applying new technology".

X2 = 20 (age of household heads); X3=12 (Education level); X4=5 (Agricultural land area); X5=1 (Access to credit); X6=1 (Other income from agriculture); X7=1 (Age of household heads); X8=4 (number of contact times with extension in one crop); X9 = 1 (Feel useful); and X10 = 1 (Distance from the house to the nearest market).

DISCUSSION AND CONCLUSIONS

Firstly, the study has identified five groups of factors affecting the decision to adopt new technology, including: Human capital, Physical capital, Social capital, Perception of risk/ uncertainty, and Market Access.

The group of factors "Human capital" includes: Age, Education level of household heads. This result is similar to the results of a study on rural areas in Tanzania by Berresaw *et al.* (2013).

The group of factors "Physical capital" includes: Agricultural land area, Access to credit, Income other than agriculture. This result is similar to the results of Mutyasira *et al*. (2018) on the Ethiopian highlands and Kassie *et al*. (2013) on rural Tanzania.

The group of factors "Social capital" includes: Participation in farmer associations, farmer unions, agricultural extension clubs and level of contact times with agricultural extension officers. This result is similar to the results of studies on rural areas in Tanzania (Berresaw *et al*., 2013).

Factors of "Uncertainty" and "Accessibility to market" include: Perceived usefulness, Distance from home to the nearest market. This result is similar to the study on rural Tanzania by Meike & Camilla (2014) and Berresaw *et al.* (2013).

Second, the study has determined the level of impact of each factor from strong to weak: Age of household head; Access to credit; Feel useful; Agricultural land area; Other income from agriculture; Knowledge level; Distance from home to nearest market; and Age of household heads.

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This result implies that in order to improve the ability of farmers to apply new technologies in agricultural production, attention should be paid to: (i) Investment in human capital in rural areas; (ii) Encourage farmers to participate in farmer associations, farmer unions, extension clubs and improve the quality of agricultural extension services in rural areas, especially at demonstration sites of new technology application; and (iii) Continue to invest in roads and a system of commercial and service centers in rural areas.

CONCLUSIONS AND RESEARCH LIMITATIONS

The present study aims to expand the theoretical framework and provide evidence in empirical results on the behavior of rice farmers choosing to apply new technologies with evidence from the Mekong Delta, Vietnam. The findings highlight the strong role of factors influencing decision to apply new technologies in production through Binary Logistic Regression analysis model.

The study has certain limitations. The survey subjects were only taken from seven provinces in the Mekong Delta, Vietnam which limits the generalizability of the study. Future research should examine different provinces and regions in Vietnam and make comparisons to improve the generalizability of the findings. Moreover, this study only considers 10 factors affecting farmer behavior to decide on new technologyy application, there are other factors that influence that this study has not mentioned.

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APPENDIX

Calculate Pi:

Assuming the initial probability of a poor household is (P_0), the probability that the household is poor will be Pi due to the effect of the variable Xi. According to Agresti (2007), Pi is defined as follows:

$$P_i = \frac{P_0 \times e^{B_i}}{1 - P_0(1 - e^{B_i})}$$

Predicted scenario for a change of poor households:

According to Agresti (2007), the predictive form of the model:

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$$E(Y / Xi) = \frac{e^{LnOdds}}{1+e^{LnOdds}}$$

E (Y/Xi): The probability that Y = 1 occurs when the independent variable X has a specific value Xi.

$$LnOdds = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + .. + B_{10}X_{10}$$

$$E(Y / Xi) = \frac{e^{B0+B1X1+B2X2+B3X3+..+B10X10}}{1+e^{B0+B1X1+B2X2+B3X3+..+B10X10}}$$

i: from 1 to 10

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