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What drives interest in precision farming: the case of Thai farmers

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ABSTRACT— Despite potential benefits of precision agriculture (PA) to improve profitability of small-scale farmers, adoption of PA in small farms is extremely low in Thailand. The purpose of this paper is to explore factors that affect the smallholder's interest in investing in PA technology, focusing on variable rate technology (VRT). The survey data of 155 small-scale farmers are used in the analysis. Farmers were asked to state their interest in VRT investment from the scenario that government provides a subsidy, and the respondent would pay for the remaining cost of VRT installation. Results from the bivariate logit model have shown that factors that significantly influence the likelihood of VRT investment are perceived usefulness and worthiness of VRT, confidence to use VRT, concerns on environmentally friendly production, use of agricultural mobile application and farm size. Family labor, old-aged farmers and types of major crop production are found to be insignificant. In addition, the intention rate to invest falls dramatically if the amount of government subsidy declined. Higher amount of government subsidy is needed to induce the VRT adoption for small-scale farmers. This study suggests policy implications such as increasing the awareness of VRT usefulness and worthiness and environmentally friendly production, promoting the use of mobile application, and providing training and capacity building to use VRT.

KEYWORDS: Precision agriculture; perception; variable rate technology; adoption; Thailand

1. INTRODUCTION

Precision agriculture (PA) is a modern farm management method using digital techniques to monitor and optimize agricultural production processes [1]. With PA technology (PAT), data are collected to assist farmers in making farm management decisions, including applications of fertilizer, herbicide, and irrigation rate, according to field variability and site-specific conditions [2]. The decisions using PAT are better than those that would be made with traditional agriculture practices, thereby improving efficient use of resources [3], and ultimately enhancing profitability while maintaining or improving production [4]. Thai agriculture has faced low labor productivity. Total factor productivity during 2013-2018 was averaged at negative 0.85 percent [5]. One of the recent agricultural policies to transform Thai agriculture is to promote adoption of advanced technologies, particularly PA to improve farm productivity. Thai government allocated budget to the projects focused on training and capacity building aimed at helping the farmers equip with modern technology and appropriate skills inter-alia. The private agribusiness firms, agricultural machinery providers and the mobile service providers in partnership with the Ministry of Agriculture have developed PAT as a tool for smallholders to manage farm efficiently. PA has already been implemented among larger farms, particularly in sugarcane and chicken production in Thailand [6]. There are very few cases where small-scale farmers have adopted PA, such as as high-valued vegetables and fruits such as melon. As most Thai farms are small-scale – 43% of them are smaller than 1.6 Ha, and another 25% are between 1.6 - 3.2 Ha [7], challenges for smallholders include high investment cost of PA, lack of ability to adopt PA and heterogeneity of cropping system. The increasing usage of mobile phone in Thailand also opened up opportunities for smallholders to use PA. Understanding factors affecting the intention of small farmers to invest in PA can lead to provide

policy implication for potential adoption. There have been many studies exploring factors affecting the adoption of PAT [8,9]. They focused on developed countries, mostly in the United States, i.e. [10, 11,12,13, 14, 20], in Australia [15,16] where farm sizes are much in larger scales than those in Thailand. Most of the empirical studies examine why farmers have or have not adopted PA technology based on the choice model. Major significant factors influencing the adoption of PA include characteristics of the farmer and the farm, farmer perception and attitude and experienced with technology such as the use of computer. However, those studies have not focused on environmental aspects and the influence of confidence in technology use and experience with mobile application in decision making. In addition, a limited number of empirical studies focused on the ex-ante factors affecting the intention to use PA. Based on the technology acceptance model, the study of [17] found that perceived usefulness has an indirect effect on the intention to adopt, mediated by perceived net benefit. The study of [18] found that perceived usefulness and perceived usability have a direct effect on the attitude to use. However, the limitation of those ex-ante studies is that the investment cost of PAT has not been included when asking intention to use.

Because precision agriculture adoption in Thailand is considered to be in the early stage, and most cases are under pilot projects, research priorities should include an ex-ante study of the determinants of PA adoption in small farms, for providing insights on the interest of new farmers to adopt PAT. The main objective of this study is to examine the determinants of the interest in PA adoption in Thailand. This study contributes to the literature in two ways. First, this is the first empirical study in Thailand that analyzes the determinant of the small-scale farmer's interest in PA adoption. Second, a specific type of PAT and investment cost that farmers have to pay for PAT is considered in this study. This study focuses on variable rating technology (VRT) as it has the potential to increase profitability and its cost is the cheapest among other types of PAT. VRT is used for variable input application allowing farmers to control the amount of inputs they apply in a specific location. As only less than 1% of farmers in the study area were aware of VRT, an information session was held for sharing details and benefits of VRT with the respondents. After that, farmers were asked to state their interest in investing in VRT providing the amount of investment that farmers have to pay. The amount of farmer's investment is based on the scenario that government subsidized for the investment cost as most small-scale farmers cannot afford VRT without government subsidy. The amount of farmer's investment is chosen from the actual expense that adopted farmers paid for VRT under the subsidy of government. Secondly, variables that represent farmers' motivation for technology adoption are empirically tested: VRT usefulness and worthniness perception. As PAT is one of the environmentally sustainable practices which requires additional investment cost, a five-point likert scale on the level of agreement on "willingness to adopt the environmentally friendly practices even though the costs are higher" is rated by farmers. Due to required high level of capabilities and skills to manage VRT, confidence in using technology and the influence of using mobile application for crop production in decision making are also empirically tested. This study also empirically tested the influences of crop produced and PA adoption whether low value crop such as rice have negatively associated with adoption.

2. Material and Methods

A survey of small-scale farmers was conducted in February 2020 in Nakorn Prathom province, the central region of Thailand. The province has diversified production including rice, sugar cane, vegetables, and fruits. Besides, one of the provincial development strategies is to promote smart farming by adopting modern technology, including PA. Understanding the determinants of intention to use PA in Nakorn Prathom province, covering different types of agriculture will provide insight to policymakers in formulating policies to scale up the adoption of PA. The field survey questionnaires included a total of 155 respondent farmers. The sample was limited to farm with less than 3.2 Ha. The Kamphaeng Saen district is chosen as major areas for rice, sugarcane and vegetable production. The Muang district is chosen as a major area for sugarcane

production. The Sam-phran district is chosen as a major area for fruit production such as pomelo and mango. In each district, the village with highest area of production is chosen. The VRT was explained and introduced to farmers before collecting information on farmer and farm characteristics, use of mobile application in agriculture, farmer's perceptions on environmentally friendly farming practices, usefulness of VRT, and worthiness of VRT investment. The interviewer asked each farmer about their interest in investing in VRT if the government subsidizes and the farmer has to pay 10,000 Baht (USD 333) for VRT installation. The value of 333 USD is derived from the current expense that adopted farmers already paid for VRT installation given the current situation that government subsidized. If the farmers indicated "interest", a farmer was asked the same question using a higher payment of 35,000 Baht (USD 1,166). If the farmers still indicated "interest", a farmer was asked the same question using a higher price 60,000 Baht (USD 2,000).

2.1 Empirical Model

The decision to invest in VRT technology can be explained by the expected random utility framework. A farmer i will decide to invest in VRT technology to maximize their expected utility of adoption. Let $E(U_{1i})$ represents the expected utility from adopting a VRT and $E(U_{0i})$ represents the expected utility from not adopting a VRT. The difference of the expected utility between two choices (adopt and not adopt) is defined by U_i

Farmer i will adopt VRT if the expected utility of adoption exceeds the expected utility of non-adoption. Adoption occurs when $U_i > 0$

Utility of farmer i is stochastic and the deterministic component of utility is a function of exogenous variables (Xi) including observable farm and farmer characteristics and perception.

. $U_i^* = \beta X_i + e_i$ (1)

However, Ui is not observable but the interest in VRT adoption (A_i) is observable as a binary variable.

A farmer is interested in VRT adoption $A_i = 1$ if $E(U_{1i}) > E(U_{0i})$

A farmer is not interested in VRT adoption $A_i = 0$ if $E(U_{1i}) < E(U_{0i})$

Equation (1) can be empirically estimated as equation (2) using a univariable logit model that uses maximum likelihood estimation.

. $A_i = \beta X_i + e_i$ (2)

$A_i = 1$ if farmers report interesting in VRT adoption, which is observable and occurred only if $U_i^* > 0$ and $Ai = 0$ if farmers report no interest in VRT adoption.

Table 1 presents lists of dependent and independent variables used in estimating the model. The dependent variable is the farmer's interest in VRT adoption, equaling one if a farmer reported interested in adopting VRT at the subsidized investment cost (USD 333). Following the literature, the independent variables represent characteristics of the farmer (old-aged farmers) and farm characteristics (farm size, family labor, type of crop produced), experience with digital technology (using agricultural mobile application) and farmer perceptions (environmental perception, perceived usefulness of VRT, perceived worthiness of VRT investment, perceived confidence in using VRT). Most previous studies found a negative influence of age on PAT adoption due to the short planning horizon [10], [11], [14]. In this study, it is expected that old-aged farmers (more than 60 years old) are less likely to be interested in VRT adoption due to a short planning horizon. A positive relationship between farm size and PAT adoption is commonly found [9-11], [16], [20], [21] due to the economy of scale and larger farms have a strong capacity to invest in PAT. This study focuses on small-scale farms, less than 3.2 Ha. The hypothesis is tested whether a farm size has a positive influence on VRT adoption among small-scale farmers. Family labor has a negative influence on VRT adoption. If there is a limited number of family labor, there is an incentive to invest in VRT to reduce the labor work on the farm. Farmers growing rice as a main crop is less likely to invest in VRT due to low-value of crop whereas those growing high-value crops such as sugarcane and vegetable and fruits are more likely to invest. Farmers using mobile

application for agriculture are more likely to adopt VRT as they gained experience and are familiar with digital technology. For the farmer perception, the agreements on the statements regarding environment-friendly farming practices, usefulness of VRT, perceived worthiness of VRT investment and confidence in using VRT are evaluated using a five-point Likert scale where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 =strongly agree. The more a farmer perceives the usefulness of VRT (in terms of reducing the use of inputs, better managing farms with a better decision, reducing production cost, increasing yield and profit) or the more worthiness of VRT investment a farmer perceives that its benefits outweigh costs, the higher the likelihoods to invest in VRT. Farmers with a higher degree of confidence in using VRT are likely to invest in VRT. Lastly, farmers with a higher level of agreement that environmentally farming practice are required even though the costs are higher would be more likely to invest in VRT.

Table 1. Variables used in the empirical model

Name	Description	Mean	S.D.
Adoption of VRT	Dummy variable 1 if interesting in adopting VRT,0 otherwise	0.439	0.499
Old-aged farmers	Dummy variable 1 = Old-aged farmers whose age is over 60 years old, 0 otherwise	0.645	0.480
Farm size	Total cultivation farming size (Ha)	1.486	0.944
Family labor	Numbers of family labors (person)	1.890	0.786
Type of crop produced	Dummy variable 1= growing rice 0= growing sugarcane, vegetable&fruits	0.4193	0.495
Using agricultural mobile application	1= Use 0 = Don't use	0.374	0.485
Environmental perception	Degree of agreement regarding "Farmer is willing to adopt environment farming practices even though the cost of adopting is higher" Likert scale 1-5 (1=Strongly disagree, 5 strongly agree)	2.994	1.326
Perceived usefulness of VRT	The average mean score of factors regarding perceived usefulness of VRT from components derived from the factor analysis (1)	3.601	0.8653
Perceived worthiness of VRT investment	Degree of agreement regarding " VRT benefits outweigh VRT costs " Likert scale 1-5 (1=Strongly disagree, 5 strongly agree)	3.264	1.225
Perceived confidence in using VRT	Degree of agreement regarding "Farmer is confident in using VAT " Likert scale 1-5 (1=Strongly disagree, 5 strongly agree)	2.597	1.223

Note (1) Perceived factors regarding the usefulness of VRT included the degree of agreement on the statements "VRT reduces the use of fertilizer", "VRT reduces the use of herbicides", "VRT reduces reduce water use", "VRT reduces labor use", "VRT helps to better manage farms with a better decision" "VRT reduces production cost" "VRT increases yield" and "VRT increases net income". Source: authors' survey

3. Result and Discussion

3.1 Interest in VRT Adoption

After explaining VRT to farmers, the interviewer asked each farmer the intention to use VRT if the government subsidizes by paying for the first-time investment cost for VRT and the farmer pays USD 333 for installation. The farmer survey results indicate that about 48 % of sampled farmers would be interested in paying for VRT. The intention rate tends to decline substantially to 4 % if the amount of farmer's investment in VRT increases to USD 2,000 (Table 2). This implies that the amount of government subsidies has a substantial impact on potential demand.

Table 2. Intention rate according to the amount of farmer's investment in VRT

Amount of farmer's investment in VRT	USD 333	USD 1,166	USD 2,000
Intention rate	48%	19%	4%

Source: authors' survey

Using the expenses that farmers pay for VRT of 333 USD as a benchmark, 68 farmers (48% of sampled farmers) would be interested in paying for VRT. Table 3 shows different characteristics between intended and non-intended farmers.

Table 3. Characteristics of non-intended and intended farmers

	Non-intended farmers (N=87)	Intended farmers (N=68)	Test-Statistics (P value)
Farmer's age (years)	56	53	T-Test=1.61(0.11)
-25-60 years	60%	70%	Chi2 = 1.95 (0.16)
-more than 60 years	40%	30%	
Farm size (Ha)	1.34	1.67	T-Test=-2.13(0.03*)
Numbers of family labor (person)	1.80	2.0	T-Test=-0.78(0.43)
Major crop produced			Chi2=0.68(0.41)
-Rice	60%	40%	
-Non-rice (sugarcane, vegetable & fruits)	53%	47%	
Use of agricultural mobile application			Chi2=8.19(0.00)***
-Don't use	65%	35%	
-Use	59%	41%	
Farmer perceptions*(1)			
-Perceived usefulness of VRT (Average score)	3.33	3.95	T-Test=-4.68(0.00)***
-Perceived worthniness of VRT investment (Average score)	3.01	3.58	T-Test=-2.99(0.00)***
-Confidence in using VRT (Average score)	2.05	3.28	T-Test=-7.06(0.00)***
-Environment-friendly farming practice (Average score)	2.87	3.14	T-test =-1.27(0.20)

Remark *(1) Score 1-1.8 = strongly disagree, Score 1.81-2.6=disagree, Score 2.61-3.4=neutral, Score 3.41-4.2= agree, Score 4.21-5=strongly agree

Note: *represents 5%, **1%, and *** 0.1% significance levels

Source: authors' survey

According to table 3, non-intended farmers are slightly insignificant older than intended farmers even though

intended farmers have less proportion of old-aged farmers more than 60 years old. Intended farmers have a significantly higher average land size than those non-intended farmers. On average, both intended and non-intended farmers have about 2 family labor working in full-time farming. In addition, 40% of total rice farmers show interest in adopting VRT whereas 47% of total non-rice farmers show no interest in adopting VRT. However, there is no significant relationship between the intention to use VRT and the type of major crop produced. Perceptions of VRT usefulness and worthiness are statistically different between non-intended and intended farmers. Non-intended farmers perceive VRT usefulness and worthiness as neutral (Avg <3.4) whereas intended farmers have a strong agreement on VRT usefulness and value for money (Avg> 3.4). However, the concern over environmentally-friendly production is not significantly different between two groups. Both intended and non-intended farmers have neutral agreement on the statement "I will adopt environmentally friendly practices even though the costs are higher "(Avg <3.4)

Table 4. Results from the logistic regression model of the factors influencing farmer's interest in VRT investment

	Model 1		Model 2	
	Coefficient	Marginal Effect	Coefficient	Marginal Effect
Old-aged farmers	-0.2510 (0.4149)	-0.0609(0.1011)	-0.5388(0.4631)	-0.1317(0.1129)
Farm size	0.0786 (0.0365)*	0.0190(0.008)*	0.0471(0.0385)	0.0114 (0.0935)
Family labor	0.3016 (0.2443)	0.0729(0.0590)	0.3042 (0.2575)	0.0739(0.0624)
Growing rice as major crop	-0.5150 (0.4432)	-0.1229(0.1039)	-0.4129 (0.4521)	-0.0993(0.1075)
Use mobile application for crop production	0.7666 (0.4032)*	0.1860(0.0968)*	0.7522 (0.4304)*	0.1832(0.1036)*
Perceived usefulness of VRT	0.9011 (0.2621)***	0.2178(0.0624)***		
Confidence in using VRT			0.9367 (0.1984)***	0.2275 (0.0481)***
Perceived worthiness of VRT investment	0.3839 (0.1652)*	0.0928(0.0396)*	0.3648(0.1764)*	0.0886(0.0426)*
Environmental farming practice	0.3315 (0.1497)*	0.0801(0.0360)*	0.3330 (0.1610)*	0.0809(0.0389)*
N	155		155	
LR Chi2(8)	40.85 (prob>chi2=0)		54.88(prob>chi2=0)	
Pseudo R2	0.1922		0.2596	

Note: *represents 5%, **1%, and *** 0.1% significance levels. Standard errors are in parentheses. Source: authors' survey

The results of the logit model on factors influencing farmers' interest in VRT investment are presented in Table 4. Two separate models are estimated to address the possible multicollinearity between the farmer's perception of the usefulness of VRT variable and the confidence to use VRT variable. Model 1 includes the VRT usefulness variable but not the confidence to use VRT variable. Model 2 includes the latter but not the former. The LR chi2 showed that both logit models are statistically significant (p = 0.000). In addition, the value of variance inflation factor (VIF) of each independent variable is less than 10, showing that there is no

serious multicollinearity. The perceived usefulness of VRT and the perceived confidence in VRT use have the greatest influences on the likelihood to invest in VRT in model 1 and 2 respectively. Farmers with a higher degree of agreement that PA is useful in terms of reducing inputs and cost of production and of increasing yields and net income have 21 percent higher chance to adopt VRT than those who have less degree of agreement. Similar results on the positive impact of the profitability perception on the PA adoption are reported [14], [19]. Farmers with a higher degree of confidence in using VRT have 23 percent higher chance to invest in VRT than those who have less degree of confidence. This shows that the perceived usefulness of VRT and level of confidence toward using VRT positively influence the interest in investing in VRT. The use of mobile application for crop production is found to be significant and positively determined the interest in VRT adoption in both models. Changing from a farmer not using mobile application for crop production to using the application, the chance of intending VRT adoption increases by 18-19 percent. This implies that the use of mobile application makes the farmer more familiar with technological operation and increasing the interest in VRT adoption. Farmer perceptions regarding the worthiness of VRT investment and environmental perception are statistically significant in explaining the interest in VRT adoption in both models. Besides, the magnitude of coefficients is similar in both models. The more a farmer perceives the worthiness or the benefits of VRT outweigh the cost, the higher the likelihood to invest. Farmers who perceive a higher degree of worthiness have 9 % higher chance to adopt VRT than those who perceived less degree of worthiness. This result is consistent with [20]. Farmers that perceived stronger degree of agreement with this statement "Farmer is willing to adopt environmentally friendly practice even though the cost of adopting is higher" has 8 % increase in the likelihood to adopt VRT than those who have less degree of agreement with this statement. Farm size was found to be a positively significant factor encouraging the adoption of VRT for the model 1. Results on marginal effects show that a unit increase in farm size will increase the likelihood of VRT adoption by 1.9%, ceteris paribus. This result confirms that farmers with larger farm size are more likely to invest in VRT. Similar results were found in other studies; for instance, [9- 11], [16], [20], [21]. This shows that the economy of scale is crucial for small-scale farmer's interest in VRT investment. However, the farm size is insignificant in explaining the interest in VRT investment in model 2. This might be due to the correlation between farm size and confidence in using VRT. It is expected that a farmer with larger farm size will have higher level of confidence in using VRT. On the other hand, family labor, old-aged farmers and types of major crop production are found to be insignificant.

4. Conclusions and Recommendations

This study aims at empirically exploring the determinants of interest in PA adoption, focusing on VRT. The study uses survey data of 155 small-scale farmers in Nakorn Pathom province of Thailand. Results of the survey indicate that 48% of respondents are interested in paying USD 333 for VRT. Thai small- scale farmers are more likely to invest in VRT if they perceive that environmental-friendly production is highly required even though the costs are higher, perceive a higher degree of VRT usefulness and worthiness, and are more confident in using VRT. The use of mobile application for crop production have a positive effect on the likelihood to invest in VRT. The specified price of VRT (USD 333) used for asking the interest in VRT adoption is substantially far below the actual VRT cost. In addition, the potential adoption rate tends to decline substantially to 4 % if the VRT payment increases to USD 2,000. This suggests that subsidies are needed to be higher to induce the adoption for small-scale farmers. In addition, the government should provide an incentive to encourage more private sectors to invest in developing the VRT so that the cost of technology can be reduced. Strengthening farmer production group should be promoted in order to create larger-scales and build a business model of using VRT that it is feasible and profitable for a group of small-scale farmers to invest in VRT. Promoting farmers to use ICT via mobile application can enhance the intention to adopt VRT. Training and capacity building in VRT use can also help small-scale farmers to have more confidence in using VRT, increasing the likelihood to adopt VRT. Improved communication focusing on the benefits of

VRT and environmental awareness would also enhance VRT adoption.

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