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Determinants of smartphone adoption and its benefits to the financial performance of agricultural households: Evidence from Hoa Binh province, Vietnam

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ABSTRACT
Mobile phone usage has come to play a vital role in the enhancement of farmers' agriculture business. Currently, the adoption of mobile phone technology is considered an important factor in enhancing farmers' access to knowledge of the agricultural market situation. This paper studies the determinants of smartphone adoption in agricultural production and examines the roles smartphone use plays in promoting agricultural firms' performance. We collected research data from 389 agricultural households in Hoa Binh Province, Vietnam. We considered the impacts of both farmer and farm characteristics on the adoption of smartphones in agriculture. The farmers' characteristics we examined included the influences of age, education, and gender. For the farm characteristics, we considered the impacts of farm size, farm diversification, and farm location. Using the PLS-SEM method, the results showed that gender had no impact on household smartphone adoption in agricultural production, while education, farm size, farm diversification, and farm location each had a positive effect on smartphone adoption. Farmer age and farm location both impeded smartphone adoption. In addition, as per our expectation, the use of smartphones in agricultural production helped increase the farm's financial performance. Based on these findings, we offer suggestions to policymakers and researchers in the field of agriculture technologies.

Contribution/Originality: This paper is the first to study determinants of smartphone adoption in agricultural production and the roles smartphone use plays in promoting agricultural firms' performance. Moreover, this is the first study to examine smartphone adoption in agriculture in Hoa Binh province, Vietnam.

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1. INTRODUCTION

Agriculture plays a vital role and is considered the backbone of the national economic system in many countries. Agriculture has a wide range of effects on society, including the provision of food, habitat, and employment, the provision of raw materials for food and other products, and the development of robust economies through trade. Agriculture not only provides food and raw materials but also helps reduce poverty, raise incomes, and improve food security for 80% of the world's poor, who live in rural areas and work mainly in farming (World Bank).

To ensure the efficiency of the agricultural value chain, many countries have applied digital technologies in agriculture. The digital revolution has been transforming agribusiness worldwide (Bronson & Knezevic, 2016). The pervasiveness of information and communication technologies (ICTs) has created a set of new solutions for the agribusiness value chain (Kamilaris, Kartakoullis, & Prenafeta-Boldú, 2017). Digitalization can be applied to all steps of the agricultural value chain, including planning, inputs, on-farm production, storage, post-harvest processing, transportation, and access to markets. Among ICTs, the increasing use of smartphones is changing agricultural processes. The introduction of smartphones has resulted in access to new services and applications, such as information on market access, weather, and plant health, as well as education and other services (Bhaskar, Murthy, & Sharma, 2017). Studies have revealed that smartphones have a positive impact on sustainable poverty reduction and identified accessibility as the main challenge in harnessing the full potential (Bhavnani, Chiu, Janakiram, & Silarszky, 2008). The adoption and use of smartphones may have an impact on how farmers combine and use various inputs (such as labor, capital assets, fertilizers, and pesticides) in the production of crops (Khan et al., 2021). Additionally, smartphones appear to be a viable option for farmers, allowing them to access government information and conduct business with public entities whenever and wherever it is convenient for them (Karetsos, Costopoulou, & Sideridis, 2014).

The advantages of smartphones include affordability, wide ownership, voice communication, and instant and convenient service delivery. For these reasons, the number of smartphone applications (smartphone apps) is increasing exponentially, facilitated by the evolution of mobile networks and the increasing functionality and falling prices of mobile handsets (Qiang, Kuek, Dymond, & Esselaar, 2012). An increasing number of smartphone apps provide access to agriculture and allied sector information. The main advantage of smartphone apps for farmers is that they provide easy access to information on the farmer's mobile. The information is stored on the smartphone itself for easy access; it may include the details of a range of practices, pest and disease information, scheme-related information, and more. Where the information is dynamic in nature, for example, weather details, market prices, and advisory services, smartphone apps require Internet connectivity to fetch the data from back-end server databases (Bhaskar et al., 2017). However, the use of smartphones for agriculture faces many challenges, especially in rural areas. A poor network signal, unfamiliarity with smartphone features, and a lack of practical knowledge are just some of the many barriers to the use of smartphones in promoting the agricultural value chain (Ogunniyi & Ojebuyi, 2016).

The agriculture sector plays a crucial role in Vietnam's economy and society. In Vietnam, the sector includes crop production, livestock, fisheries, and forestry. The agricultural sector helps to ensure national food security by supplying sufficient food for Vietnam's population of 96.48 million people. It accounted for about 13.96% of the total gross domestic product (GDP) of Vietnam in 2019. However, in recent years, population increase, urbanization, and climate change have presented several challenges to the Vietnamese agriculture sector, necessitating a restructuring to adapt to the new circumstances. The Vietnamese agricultural sector has gradually intensified its ICT use to improve its productivity, quality, and competitiveness. It is anticipated that digital transformation and high-technology applications will enable the industry to increase agricultural productivity, adapt to climate change, ensure farmers' incomes, and decrease food waste.

In this research, we studied the use of smartphone applications in the agricultural value chain in Hoa Binh Province, Vietnam (we describe this location in detail in Section 3). We explored how smartphone use could enhance the agricultural value chain in this area and what the barriers to using smartphones were for participants in the value chain. Our findings should allow us to propose some suggestions for promoting the use of smartphones to optimize the agricultural value chain of Hoa Binh province, Vietnam.

The findings of the partial least squares structural equation modeling (PLS-SEM) indicate that while education, farm size, farm diversity, and farm location all have favorable effects on smartphone adoption, gender has no bearing on the household's use of smartphones for agricultural output. Two barriers to smartphone adoption are farmer age and farm location. Additionally, as expected, the use of smartphones for agricultural purposes contributes to an improvement in the financial performance of producers. The contributions of this study are twofold. First, this paper comprehensively considers the impact of both farmer and farm characteristics on smartphone adoption in agricultural production processes. Second, to the best of our knowledge, this is the first paper to investigate factors influencing smartphone adoption in agricultural production in Vietnam and provides evidence for the positive effects of smartphone adoption on the financial performance of agricultural households.

The remainder of the paper is organized as follows. Section 2 reviews the literature and develops the hypotheses. Section 3 introduces the study area. Section 4 describes the data. Section 5 outlines and discusses the results. Section 6 sums up the conclusions.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Rogers (2003) theory on the diffusion of innovation has been applied in numerous scientific areas to explain the adoption of technology by individuals, social groups, and organizations. The theory includes several variables that are expected to influence smartphone adoption in agriculture. These factors include both adopter and company characteristics. Accordingly, the hypotheses take into account both farmer characteristics and farm characteristics.

2.1. Farmer Characteristics

Age is one of the most frequently studied qualities in the agricultural economics literature, and it is believed to have a significant impact on the adoption of technology and innovations (Ghadim & Pannell, 1999). According to Tamirat, Pedersen, and Lind (2018), younger farmers are more likely to use high-tech devices due to a greater interest in new technology. Compared to other producer groups, younger farmers (those under 45) and those with larger operations are more likely to use digital media, such as full desktop websites, mobile websites, and social media platforms. Additionally, compared to producers with smaller businesses, those with extensive revenue-generating activities ($1 million or more in gross revenues) are far more likely to deem digital channels important. In addition, Tiffin and Balcombe (2011) demonstrated that older British farmers are less likely to use a computer. Similarly, the age of the individual making smartphone adoption decisions is a significant factor. A recent study by Kongaut and Bohlin (2016) indicated that older individuals in Sweden were less likely to adopt smartphones than younger individuals. Therefore, we hypothesize that:

H1: Age has a negative effect on smartphone adoption in agriculture.

Next, it is anticipated that farmers' education will impact their decision to accept new technologies (Lin, 1991). However, the literature regarding the adoption of mobile phones is contradictory. Daberkow and McBride (2003) found that a higher level of education was favorably associated with technology awareness, but not actual adoption. Similarly, education level was believed to be a significant factor influencing computer and Internet usage in agriculture (Briggeman & Whitacre, 2010). Regarding cell phones, Kongaut and Bohlin (2016) discovered that those with lower levels of education were less likely to own one. Therefore, we hypothesize that:

H2: Education has a positive effect on smartphone adoption in agriculture.

Gender plays a distinct role in the decision processes that drive the adoption of information technology (Venkatesh, Morris, & Ackerman, 2000). Regarding mobile phone adoption, Paustian and Theuvsen (2017) observed that gender has not been acknowledged as a significant driver because it is assumed that the majority of farmers are male. However, in agriculture more generally, male farmers were more likely than female farmers to accept new techniques or innovations (Doss & Morris, 2000). According to Theis, Lefore, Meinzen-Dick, and Bryan (2018), a gender gap in technology adoption persists for many agricultural technologies, even those that are targeted at women. Therefore, we hypothesize that:

H3: Male farmers are more likely to own a smartphone.

2.2. Farm Characteristics

The literature indicates that larger farms are more likely to embrace mobile phones due primarily to economies of scale (Pierpaoli, Carli, Pignatti, & Canavari, 2013). The size of a farm is also a major factor in computer and Internet adoption decisions. Numerous studies have demonstrated that only farms of considerable size will embrace new tillage technology with higher fixed costs but lower variable labor costs. Smaller farms cannot afford to engage in modern tillage technology due to fixed capital expenses (Brown, Ferguson, & Viju-Miljusevic, 2020).

Gloy and Akridge (2000) discovered a positive correlation between farm size and computer adoption. In addition, Mishra and Park (2005) found that the size of US farms increased the number of Internet applications they utilized for business purposes. Therefore, we hypothesize that:

H4: Farmers on smaller farms are less likely to buy a smartphone and, as a result, less likely to use smartphones for agricultural production.

It has been demonstrated that enterprise diversification has no statistically significant effect on mobile phone adoption (Walton, Reed, & Macagno, 2008). According to Amponsah (1995), diversification had little effect on cell phone use in agriculture. In contrast, Mishra and Park (2005) suggested that more diversified farms require farmers to make more decisions and collect more information; hence, they were more inclined to utilize mobile phone technology. Therefore, we hypothesize that:

H5: Diversification has a positive effect on smartphone adoption.

Due to differences in climatic, soil, and geographical factors, the farm's location also plays a vital role (Paxton et al., 2011). Regarding ICT, the location's digital infrastructure may serve as either a facilitator or a barrier to adoption. For instance, territorial limitations to Internet access are frequently caused by the location of digital infrastructure (Philip, Suman, Menon, & Dhanya, 2017). Due to its digital infrastructure, housing also has a significant impact on mobile phone usage (Srinuan, Srinuan, & Bohlin, 2012). Therefore, we hypothesize that:

H6: Location has a negative effect on smartphone adoption.

2.3. Mobile Phone Adoption and Financial Performance

Based on the above literature review, we developed a research framework as shown in Figure 1. In addition to the above-mentioned hypotheses, we would also like to discover how the smartphone decision affects the financial performance of agricultural households. Khan et al. (2022) showed that the adoption of mobile Internet technology boosted agricultural output, which in turn increased the revenue of agricultural producers. Even though mobile phones can serve as a catalyst for increased farm production and rural incomes, the quality, timeliness, and credibility of this information must be conveyed to farmers to fulfill their requirements and expectations (Mittal & Tripathi, 2009). Therefore, we hypothesize that:

H7: Smartphone adoption has a positive effect on the financial performance of agricultural households.

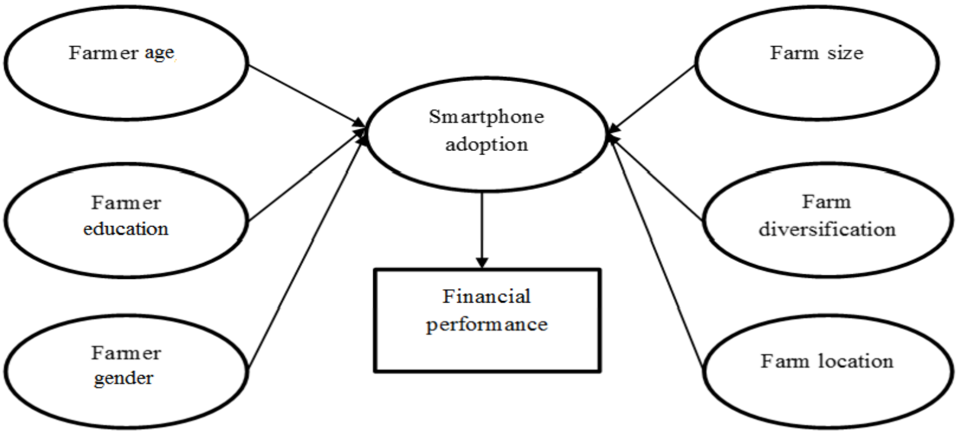

Figure 1. Research framework.

3. STUDY AREA

Hoa Binh is a mountainous province of northwestern Vietnam, more than 70km from Hanoi Capital, with three border regions, including the Northwest, Northeast, and North Central Coast of Vietnam. Hoa Binh province has 11 districts, a city with 210 communes, wards, and towns. The population is 854,131 and includes 6 main ethnic groups, of which the Muong ethnic majority is over 63%. The province covers an area of 4590.57 square kilometers. In 2020, the GDP per capita of the province was estimated to be $2625.

The total area of Hoa Binh Province is 459,524.36 hectares. Agricultural land is 307,986 hectares, accounting for 67% of the total area, including 55,151 hectares of farmland, 251,315 ha of forest land, 1,335 ha of aquaculture land, and 185 ha of other agricultural lands (Hoa Binh Province website). Due to its geographical position adjacent to the Red River Delta and Hanoi city, as well as its natural conditions and rich and diverse cultural characteristics, Hoa Binh province developed a tradition of agriculture.

Hoa Binh Province has soil and climate diversity suitable for agricultural and forestry development; it has highly fertile land, forest land, agricultural land, and large unused surface land suitable for investment in the field of afforestation and industrial plants, enabling medicinal and high technology agricultural production. For aquaculture, Hoa Binh Province contains a network of rivers, streams, lakes, and marshes distributed throughout all districts and cities. Da River flows through Mai Chau, Da Bac, Tan Lac, Hoa Binh city, and Ky Son districts. Hoa Binh reservoir, with its surface area of about 8,000 hectares, provides convenient conditions for agricultural production and aquaculture. Thanks to the above mentioned conditions, Hoa Binh Province's agricultural products have gradually come to dominate the domestic and international markets, significantly contributing to the socio-economic development of the province. Many specialty products can be mentioned, such as red flesh dragon fruit and honey from Ky Son district, Huong Chi longan from Kim Boi district, purple sugarcane and oranges from Cao Phong district, and more.

4. DATA DESCRIPTION

4.1. Data Collection and Analysis Method

The research sample was drawn from agricultural households in Hoa Binh Province, Vietnam. Interviewees were randomly selected from the population for questionnaire administration. To assess the research model and test the stated hypotheses, the questionnaire survey was used to collect data for this study. All observed variables were defined using a Likert scale, which ranged from 1 (strongly disagree) to 5 (strongly agree). The questionnaires were answered by owners, managers, or employees where there were no owner-managers available. Face-to-face, drop-off, and email methods were employed to distribute the questionnaire, culminating in 389 returned copies. The collected data was subsequently cleaned and analyzed using structural equation modeling (SEM) in SmartPLS software.

4.2. Demographic Profile

Table 1 shows the demographic profile of the study participants. A majority of the respondents had a low level of education (78.66% had post-secondary education or lower), while a very low proportion of respondents had a higher degree. For this reason, it is unsurprising that the monthly income of most of the respondents was quite low (63.75% earned less than 10 million Vietnam Dong (VND; approx. USD 400 per month). In terms of gender and age, the sample equally covered all categories.

5. RESULTS AND DISCUSSION

Table 2 shows the hypothesis testing results of the PLS-SEM model. The estimated results show that H3 was rejected, while H1, H2, H4, H5, H6, and H7 were supported. Specifically, gender had no impact on smartphone adoption for agricultural production in households, whereas education, farm size, farm diversification, and farm location each had a positive effect on smartphone adoption. Farmer age and farm location were two obstacles to smartphone adoption. Moreover, as we expected, the use of smartphones in agricultural production helped increase the farm's financial performance. Among the three farmer traits, farmers' age and educational attainment had a strong positive correlation with their desire to embrace smartphone technology; however, gender had a negligible positive correlation. This finding is in line with research by Poushter (2016) and Alampay (2006), who found that age had a significant impact on ICT use. Younger farmers were more likely to employ mobile devices than their elder counterparts. The generation to which new technologies are introduced is more appreciative of them.

Table 1. Demographic profile.

Variables	**Frequency**	**Percentage (%)**
Gender		
Male	201	51.67%
Female	188	48.32%
Age		
Under 30	27	6.94%
30–39	85	21.85%
40–49	152	39.07%
50 or above	125	32.14%
Education		
Secondary education or lower	112	28.79%
Post-secondary education	194	49.87%
Short-cycle tertiary education	56	14.50%
Bachelor's degree	24	6.17%
Graduate degree	3	0.76%
Farm size (Total farm value)		
Less than VND 100 million	47	12.08%
VND 100–200 million	201	51.67%
VND 200–300 million	84	21.59%
VND 300–400 million	37	9.51%
More than VND 400 million	20	5.14%
Farm diversification		
Less than 5 agricultural products	89	22.88%
5–10 agricultural products	162	41.65%
10–15 agricultural products	64	16.45%
15–20 agricultural products	57	14.65%
More than 20 agricultural products	17	4.37%
Farm location (Far from prefectural city)		
0–20 km	86	22.11%
20–40km	93	23.91%
40–60km	106	27.25%
60–80km	74	19.02%
80–100km	30	7.71%
>100km		
Smartphone adoption		
Yes	285	73.26%
No	104	26.74%
Yearly profit		
Less than VND 100 million	37	9.51%
VND 100–200 million	183	47.04%
VND 200–300 million	89	22.88%
VND 300–400 million	34	8.74%
More than VND 400 million	46	11.83%
Total	389	100%

Table 2. Testing results of path coefficients.

Hypothesis	**Relationship**	**Coefficient**	**Standard deviation**	**P value**	**Conclusion**
H1	Farmer age -> Smartphone adoption	-0.483**	0.189	0.0109	Supported
H2	Farmer education -> Smartphone adoption	0.592***	0.039	0.0000	Supported
H3	Farmer gender -> Smartphone adoption	0.326	0.328	0.3208	Unsupported
H4	Farm size -> Smartphone adoption	0.973**	0.391	0.0132	Supported
H5	Farm diversification -> Smartphone adoption	0.784***	0.119	0.0000	Supported
H6	Farm location -> Smartphone adoption	-0.892***	0.307	0.0038	Supported
H7	Smartphone adoption -> Financial performance	0.985***	0.089	0.0000	Supported

Note: ** and *** indicate coefficients significant at 10% and 5% significance levels, respectively.

Poushter (2016) found that individuals from Generations Y and X tend to possess and utilize cell phones more frequently than their elder counterparts. Although cell phones help farmers interact with one another, increase production, and stay up to date on agricultural information, many elderly farmers lack confidence with technology. The challenges to smartphone adoption for elderly farmers may include a lack of knowledge and skills, fear, a lack of technical self-efficacy, and trust concerns.

According to a study on income and education conducted in the Philippines by Alampay (2006), persons with higher incomes and more education tend to use ICT more frequently than those with lower incomes. Low-educated farmers may not be able to embrace the most recent digital technologies (such as mobile phones, the Internet, and computers) to boost agricultural output because they lack the necessary training and skills. Moreover, Ma, Renwick, Nie, Tang, and Cai (2018) mentioned that increasing family incomes can directly affect how many rural inhabitants use smartphones, and smartphone use in turn increases revenue by enabling online financial transactions, simplifying administrative duties, expanding social networks, offering technical services, and minimizing risk exposure.

Regarding farm size, large farms may have more multifaceted decision-making and organizational complexity (Ghimire, Huang, & Poudel, 2015). Thus, a smartphone might be used to construct strong farm business strategies, including banking and the acquisition of operating resources for long-term agricultural development. Furthermore, smartphones can be used to reach staff and advisors, supporting the notion that farmers with large farms may have a higher need for cutting-edge technology. As a result, farmers on big farms may utilize smartphones to swiftly collect data. Specifically, smartphones enable farmers to collect location and time-varying pricing and weather information. In short, farmers who manage large farms are more likely to use smartphones.

According to our model, farm diversity affects smartphone uptake as well. This result is consistent with Roco, Engler, Bravo-Ureta, and Jara-Rojas (2015). Diversified farms may have a greater need for skills and use smartphones for a variety of production operations and information collecting. Therefore, there may be a link between farm diversification and smartphone use. The use of smartphones is more likely since the owners of very diverse farms must acquire more knowledge to make agricultural decisions. Diversified businesses and farms, as the results of Kaila and Tarp (2019) show, have greater information technology needs.

According to our model's findings, farm location has a detrimental impact on smartphone uptake. According to Bellon-Maurel et al. (2015), location may be interpreted as a proxy for internet access. In terms of mobile broadband coverage, the current study's findings demonstrate that the coverage and long-term evolution of general mobile telecommunications services in some regions are substantially lower than in other regions, which may explain the findings. Furthermore, cultural differences (for example, farmers in some areas may be more traditional) may make it difficult to adopt new technologies like smartphones. Although the current study did not explicitly evaluate this factor, it may be concluded that farm location will affect smartphone uptake.

Finally, our findings indicate that having and utilizing a mobile phone can improve farmers' financial success. Smartphone adoption benefits farmers in many ways. Smartphones have made it possible for farmers to obtain information regarding markets and the weather. Through this vital technology, they can maintain direct contact with market personnel and provide their produce at competitive costs (Michels et al., 2020). The use of smartphones also keeps them informed of weather forecasts for the application of agricultural inputs, such as fertilizer and pesticides, which may be impacted by unanticipated weather or natural disasters as relayed by the meteorological department. This technology has also provided farmers with a new orientation and strategy for communicating directly and exchanging information about current advances (Nie, Ma, & Sousa-Poza, 2021). In addition, smartphones save farmers time and energy, which ultimately increases their income. Thanks to mobile phones, farmers are now able to contact market brokers and clients directly to sell their produce at a good price (Siaw, Jiang, Twumasi, & Agbenyo, 2020). Many studies have identified potential mechanisms underlying the positive relationship between phone use and agricultural productivity, such as the use of mobile phones to connect farmers to buyers (Martin & Abbott, 2011), acquire farm inputs (Asif, Uddin, Dev, & Miah, 2017), reduce transaction costs and time associated with agricultural activities (Mwantimwa, 2019), and exchange agricultural information and recommendations (Mwantimwa, 2019). For instance, a farmer may use his phone to contact a fertilizer supplier in town, purchase fertilizer, and then hire assistance in transporting the fertilizer to the farm, saving both time and money.

6. CONCLUSION

Smartphones are increasingly important in agriculture and are significantly changing the agricultural value chain worldwide. They provide timely access and useful information for farmers, enterprises, and governments in managing all aspects of agriculture. This paper studies the determinants of smartphone adoption in agricultural production and the roles smartphones play in improving agricultural firms' performance. Using the PLS-SEM method, the results showed that gender has no impact on smartphone adoption for agricultural production in households, whereas education, farm size, farm diversification, and farm location each have a positive effect on smartphone adoption. Farmer age and farm location are two barriers to smartphone adoption. In addition, as we expected, the use of smartphones in agricultural production enhances farms' financial performance.

This paper contributes to the body of knowledge by identifying critical factors that influence the adoption of smartphones in agriculture and their benefit to the financial performance of agricultural households. The findings may be of interest to policymakers, researchers in the field of agriculture technologies, and developers and providers of farm equipment and precision agriculture technologies that integrate with smartphones, as the findings provide information on smartphone use and the key factors that influence smartphone adoption. Some policy implications can be drawn from our results. First, the government needs to pay attention to improving farmers' education, farm size, farm diversification, and farm location. These factors will ensure farmers have better opportunities to apply high technologies in their agricultural production processes. Secondly, the government should focus on expanding and speeding up the mobile infrastructure so that farmers can use smartphones more easily. This will enable farmers to take full advantage of smartphones and reap the agricultural benefits. Finally, to encourage farmers to use smartphones in production, financial support measures are needed to increase the number of users, thereby developing a smart value chain in which ICTs are applied in all stages.

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