Timing of Smartphone Adoption in German Agriculture – Who are the Early Adopters?

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Abstract: Smartphones suit several on-farm operational activities and farmers' daily working routine very well due to their mobility, high computing power and ability to install (agricultural) apps as needed. However, no study has yet focused on factors affecting the timing of adoption. Understanding the timing of a technology adoption and identifying characteristics of early and late adopters is consequently of great relevance to further anticipate the innovation diffusion process. The aim of this study is therefore to analyze the timing of smartphone adoption by applying a tobit regression model to a data set of 207 German farmers collected in 2019. Regression results show that, among other factors, farmers' age and risk attitude affect the timing of smartphone adoption.

Keywords: smartphone, timing of adoption, tobit regression, agricultural app, technology adoption

1 Introduction

Smartphones can be described as intelligent mobile devices with computer-like computing capacities, access to mobile internet and equipped with several sensors and camera. Furthermore, apps can be (de-)installed according to the users' needs. Thus, smartphones suit very well farmers' daily working routine due to their mobility, access to mobile internet and multifunctionality. While the adoption of smartphones [Mi20] is already investigated, no study has yet focused on factors affecting the timing of smartphone adoption in agriculture. Timing of adoption or diffusion of agricultural technologies can be understood as a gradual process, which is contingent on farmers and farm characteristics. In line with this, [Wa14] showed that farmers and farm characteristics affect timing of precision agriculture technologies (PAT) adoption. Likewise, it can be expected that farmers and farm characteristics also affect the timing of smartphone adoption. Understanding the timing of a technology adoption and identifying characteristics of early and late adopter is important to further anticipate the diffusion process. The aim of this study is therefore to analyze the timing of smartphone adoption. To do so, we applied a tobit regression model to a data set of 207 German farmers collected in 2019.

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2 Hypotheses generation

It can be expected that farmers and farm characteristics play a role in the timing of smartphone adoption in agriculture. As smartphones share characteristics of mobile phones, computers and PAT and can also integrate with PAT [Mi20], we adopted the classification of factors affecting the adoption of PAT by [Pi13]. Based on that classification, we considered competitive and contingent factors (**H9**, **H10**, **H11**, **H12**), socio-demographic factors (**H1**, **H3**, **H5**, **H6a**, **H6b**, **H7**) as well as financial resources (**H2**, **H4**, **H8**) which are most likely to affect the timing of smartphone adoption. In the following, the hypotheses are shown which are the discussed more in-depth in the results section.

- **H1**: A higher farmers' age has a negative effect on the timing of adoption (*Age*)
- **H2**: Being an agricultural contractor has a positive effect on the timing of adoption (*Contractor*)
- **H3**: Holding a university degree has a positive effect on the timing of adoption (*Education*)
- **H4**: Being a full-time farmer has a positive effect on the timing of adoption (*FullTime*)
- **H5**: Being a male farmer has a positive effect on the timing of adoption (*Gender*)
- **H6a**: Having a laptop has a positive effect on the timing of adoption (*Laptop*)
- **H6b**: Having a PC has a positive effect on the timing of adoption (*PC*)
- **H7**: A higher risk aversion has a negative effect on the timing of adoption (*RiskAtt*)
- **H8**: Being the farm manager has a positive effect on the timing of adoption (*Position*)
- **H9**: A farm serving as a training location for agricultural apprentices has a positive effect on the timing of adoption (*Apprentice*)
- **H10**: Managing a conventional farm has a positive effect on the timing of adoption (*Conv*)
- **H11**: A higher farm size in hectares arable land has a positive effect on the timing of adoption (*FarmSize*)
- **H12**: Location of the farm in the south region has negative effect on the timing of adoption (*Region*)

3 Material and methods

In the first quarter of 2019, an online survey addressed to German farmers was conducted. Farmers were invited to participate in the survey using various groups on social media platforms, agricultural online forums and newsletters. Being active in arable farming was a pre-condition to take part in the survey. The survey was divided into two parts: in the first part, farmers were asked to enter information on socio-demographic and farm-related characteristics. In the second part of the survey, the farmers were asked if they have a computer, laptop, mobile phone and smartphone. With respect to smartphone, farmers were also asked since when they used it for agricultural purposes (Variable agricultural smartphone experience (*SmExp*) in years). This variable serves as the dependent variable in the econometric analysis. A left-censored tobit regression model ($SmExp \leq 0$) is applied to the collected data set.

4 Results and discussion

4.1 Descriptive statistics

207 fully completed questionnaires remained as usable records after removing incomplete surveys. 95 % of the farmers in the sample have a smartphone. Smartphone users in the sample reported the use of smartphones for 7.62 years on average. The average farmer in our sample is 39 years old (**H1**), which is younger than the average German farmer with 53 years. 27 % of the farmers work as agricultural contractors beside arable farming (**H2**). With respect to education, 52 % of the farmers in the sample report holding a university degree (**H3**). In German agriculture, 12 % of the farmers hold a university degree. Most farmers in the sample (90 %) work as full-time farmers (**H4**), which also exceeds the German average of 48 % full-time farmers. 6 % of the farmers are female (**H5**), which almost corresponds to the German average of 10 %. 79 % of the farmers in the sample report having a PC and 66 % state they have a laptop at home (**H6**). Risk attitude was measured using the scale developed by [Do11]. A value of 5 on the scale indicates a risk neutral individuum (<5 = risk averse; >5 = risk-seeking). The average farmer of our sample can be considered to be slightly risk neutral with an average value on the scale of 5.42 (**H7**). 66 % of the participants were the actual farm manager followed by the farm successors with a share of 27 % in the sample. Only 4 % were employees and 3 % family labor force (**H8**). 66 % of the farms were a training location for agricultural apprentices (**H9**). Furthermore, 85 % of the farms were farmed as conventional farms (**H10**), which is close to the German average of 89 % conventional farms. Farm size (**H11**) amounts on average to 297.90 hectares of arable land which exceeds the German average of 65 hectares of arable land. Most farms in the sample were located in the region North (37 %) followed by region South (20 %) and region West (20). The least proportion of participants have their farm located in the region East (12 %) (**H12**).

4.2 Tobit regression results

To control for multicollinearity, variance inflation factors (VIFs) were estimated before running the tobit model. VIFs < 5 indicate that multicollinearity is no threat for the model. None of the estimated VIFs exceed the value of 5 (mean VIF = 1.19; max. 1.55). The coefficients, robust standard errors as well as marginal effects in years and corresponding significance levels are given in Table 1. Further goodness-of-fit characteristics and explanations are given below Table 1.

Tab. 1: Tobit results for the timing of smartphone adoption (N = 207) [a]

H_0	Variable	Coefficient	Robust SE	ME	p-Level	Support H_0?
Farmer characteristics						
H1	*Age*	-0.105	0.021	-0.104***	<0.001	Yes
H2	*Contractor*	0.828	0.390	0.821**	0.034	Yes
H3	*Education*	-0.520	0.412	-0.516	0.208	No
H4	*Full-time*	-1.591	0.686	-1.577**	0.020	No
H5	*Gender*	2.001	0.957	1.984**	0.036	Yes
H6a	*Laptop*	0.348	0.398	0.345	0.382	No
H6b	*PC*	0.025	0.407	0.251	0.950	No
H7	*RiskAtt* [b]	0.235	0.107	0.233**	0.029	Yes
H8	*Position* [c]					No
	FarmSuccessor	0.456	0.510	0.453	0.372	
	FamilyLaborForce	-0.293	0.716	-0.290	0.682	
	Employee	-1.131	0.998	-1.115	0.254	
Farm characteristics						
H9	*Apprentice*	0.864	0.468	0.857*	0.065	Yes
H10	*Conv*	0.823	0.540	0.816	0.128	No
H11	*FarmSize*	0.0007	0.0003	0.0007*	0.058	Yes
H12	*Region* [d]					Yes
	North	0.923	0.437	0.916**	0.035	
	West	-0.082	0.487	-0.081	0.865	
	East	0.353	0.729	0.350	0.628	

[a] Dependent variable *SmExp*; F (17, 190) = 5.67, p < 0.001; Log pseudolikelihood = -474.088; Cox-Snell Pseudo R^2 = 0.305; Nagelkerke Pseudo R^2 = 0.307; McFadden Pseudo R^2 = 0.073;

[b] Risk attitude measure on the scale developed by Dohmen et al. (2011) with 0 – < 5 = risk-averse, 5 = risk neutral, > 5 – 10 = risk-seeking

[c] Farm manager was set as the base category

[d] South was set as the base category

*p < 0.1; **p < 0.05; ***p < 0.01; SE = Standard error, ME = Marginal effect

The model supports **H1** since the marginal effect for the variable *Age* is statistically significant and negative (ME = -0.104; $p < 0.001$). The results suggest that older farmers adopt a smartphone later than younger farmers. With respect to the aim of the study, it can also be concluded that younger farmers have a higher interest in adopting a smartphone at an earlier stage than older farmers. The result also suggests that older farmers may face barriers in the adoption and use of smartphones since they may have fewer digital skills to work properly with smartphones than their younger counterparts. **H2** is supported by the model. The statistically significant marginal effect and the positive sign for the variable *Contractor* (ME = 0.821; p = 0.034) suggest that if a farmer is an agricultural contractor besides arable farming, he or she adopts a smartphone almost one year earlier than a farmer who is not an agricultural contractor. The result is plausible since this farmer is maybe in contact with several customers and also maybe has to organize his employees for which a smartphone can be used to a greater extent than a normal mobile phone. The variable **Education** has no statistically significant effect on the timing of adoption and the marginal effect has not the expected positive sign (ME = -0.516; p = 0.208). Hence, **H3** is given no support by the model. The marginal effect of the variable *FullTime* is statistically significant but has not the expected positive sign (ME = -1.577; p = 0.020). Therefore, no support can be given to **H4**. A positive effect was expected, since a full-time farmer has less competition for his time and might benefit the most from several smartphone function during day-to-day farming operations. **H5** is supported by the model since the marginal effect for the variable *Gender* is statistically significant and has the expected positive sign (ME = 1.984; p = 0.036). According to our results, a male farmer adopts a smartphone two years earlier than his female counterpart. The model shows no support for **H6a** and **H6b**. While the marginal effects have the expected positive sign, the marginal effects for the variable *Laptop* (ME = 0.345; p = 0.382) and *PC* (ME = 0.251; p = 0.950) are not statistically significant. The marginal effect of the variable *RiskAtt* is statistically significant and has the expected positive sign (ME = 0.233; p = 0.029). Hence, **H7** is supported. Adoption of new technology like smartphones at an earlier stage comes with several risks for instance unknow compatibility to the expected field of application or not comprehensively covered issues with data security and safety. Therefore, a risk-seeking farmer is more inclined to adopt a smartphone at an earlier stage. To analyze the effect of farmers' position in the agricultural holding on the timing of smartphone adoption, being the farm manager was set as the base category in the econometric analysis. However, the marginal effects for the variables *FarmSuccessor* (ME = 0.453; p = 0.372), *FamilyLabourForce* (ME = -0.290; p = 0.682) and *Employee* (ME = -1.115; p = 0.254) are not statistically significant. Hence, **H8** can be given no support by the model. **H9** is given support by the results for the tobit model. The marginal effect of the variable *Apprentice* has the expected positive sign and is statistically significant (ME = 0.857; p = 0.065). Hence, farmers who are training apprentices adopt a smartphone one year earlier than farmers who are not participating in the training of young farmers. Agricultural trainers might become aware of smartphone technology for agricultural purposes and therefore adopt them earlier than other farmers. The model does not support **H10**. The marginal effect of the variable *Conv* is not statistically significant despite having the expected positive sign (ME = 0.816; p = 0.128). **H11** is supported by the model since the marginal effect for the variable *FarmSize* is statistically significant and has the expected positive sign (ME = 0.0007; p = 0.058). However, it should be clearly stated that the marginal effect on the timing of adoption is very small. On a larger scale, an increase in 1,000 hectares of arable land only results in earlier smartphone adoption by 0.7 year. To analyze the effect of farm' location on the timing adoption, Germany was divided into four regions and region South was set as the base category. Therefore, the results have to be interpreted in relationship to the base category. The results show that farmers living in the northern region of Germany adopt a smartphone 0.916 years earlier than a farmer residing in the southern regions. The marginal effect in this case is statistically significant (ME = 0.916; p = 0.035). No statistically significance is found between southern and eastern as well as southern and western farmers since the marginal effects for the variable *West* (ME = -0.081; p = 0.865) and *East* (ME = 0.350; p = 0.280) are not statistically significant. Hence, **H12** is partly supported.

5 Concluding remarks

The main goal of this study was to gain knowledge about factors influencing the timing of smartphone adoption in agriculture. To this end, a sample of 207 German farmers was collected in the first quarter of 2019. A left-censored tobit regression model was estimated to identify farmers and farm characteristics affecting the timing of adoption. Several implications for agricultural policy makers, agricultural extension services as well as providers and sellers of smartphone and agricultural apps could be given. Since the location of the farm plays a role in timing of smartphone adoption, policy makers are encouraged to put more emphasize in mobile network expansion. Furthermore, aspects of digitalization should be included more in-depth in the training of farmers, especially in training programs for farmers who participate in the training of young farmers. Agricultural extension series should consider that older, female, risk-averse farmers may face barriers in the adoption. Likewise, agricultural extension services as well as providers and sellers of smartphones and agricultural apps should strive for the clarification of risks associated with the use of smartphones for business purposes.

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