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RESEARCH ARTICLE

Who cares what parents think or do? Observational learning and experience-based learning through communication in rice farmers' willingness to adopt sustainable agricultural technologies in Hubei Province, China

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Abstract
Sustainable agricultural technologies are of great significance in fully utilizing agricultural resources and promoting agricultural production. However, the adoption rates of these technologies are often characterized as low in rural areas in China. To figure out the potential salient determinants of rice farmers' willingness to adopt sustainable agricultural technologies, this paper, by employing the multivariate probit model and ordered probit model, particularly and firstly explores the roles of observational learning and experience-based learning through communication from parents within the household on rice farmers' willingness to adopt these technologies. Results show that there are strong complementarities and substitutabilities between sustainable agricultural technologies that rice farmers are willing to adopt, and that observational learning and experience-based learning through communication within the household do have pronounced effects on rice farmers' willingness to adopt some sustainable agricultural technologies and on their intensive use intentions. Therefore, while formulating policies to improve the adoption rates and adoption intensity of these technologies, relevant government agencies should take the complementarities and substitutabilities between sustainable agricultural technologies as well as observational learning and experience-based learning through communication from parents into consideration.

Keywords Observational learning · Experience-based learning through communication · Rice farmers · Willingness to adopt. Sustainable agricultural technologies

Abbreviations

SATs	Sustainable agricultural technologies
MVP	Multivariate probit model
OPM	Ordered probit model
S	Improved seed
B	Biopesticide
F	Soil testing and fertilizer recommendation
R	Straw returning technology
C	Intercropping
T	No-/mini-tillage
W	Water-saving technology

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Introduction

The adoption and diffusion of sustainable agricultural technologies (SATs) is critical for increasing agricultural productivity, for improving rural livelihoods and, more importantly, for accelerating sustainable agricultural development (Khonje et al. 2018). This is particularly relevant for China since it is moving from the traditional extensive mode of agricultural growth to an ecological sustainable paradigm. Actually, numerous efforts have been made by the Chinese Government to develop these technologies. For instance, *on improving the* *innovative driving*, *incentive and restrictive mechanism of agricultural green development*, released by China's Agriculture Ministry in 2017, explicitly puts forward the strategies such as providing farmers with technical guidance and training to speed up the popularization of advanced and applicable SATs (China's Agricultural Ministry 2016). However, as in much of China's rural areas, the adoption of such technologies has been slow (Luo et al. 2014, 2016).

Low adoption rates of SATs are not unique to China, and an exhaustive review of the literature suggests several types of reasons for low rates of uptake for these technologies. First, impacts of technology features and individual characteristics and perceptions have been identified (Barrett et al. 2002; Luo et al. 2016; Khonje et al. 2018). Specifically, Barrett et al. (2002) show that effective and improved agricultural practices are popular among rural Africans; apart from the significant influences of gender and education (Khonje et al. 2018), personal knowledge of and attitudes towards recommended practices are also crucial predictors of adoption (Luo et al. 2016). Second, influences of household attributes have been analyzed (Ndiritu et al. 2014; Kassie et al. 2015). Specifically, credit constrained households and those with small household size are less likely to adopt certain SATs (Ndiritu et al. 2014), while livestock owned, total farm size and farm assets have positive influence on adoption of some SATs (Kassie et al. 2015). Third, roles of institutional and other external factors have been highlighted (Shiferaw et al. 2009; Luo et al. 2014; Kassie et al. 2015). Specifically, adoption of recommended technologies is significantly affected by improved market access and access to credit (Shiferaw et al. 2009), subsidy and insurance support from government (Luo et al. 2014) as well as access to extension services and land tenure security (Kassie et al. 2015), etc. More recently, many literature have given emphasis on the role of social learning through social networks in technology adoption (Moser and Barrett 2006; Morgan 2011; Krishnan and Patnam 2013; Magnan et al. 2015; Maertens 2017), and the learning objects the researches have focused on are mainly those such as neighbors (Moser and Barrett 2006), peers with similar attitudes (Morgan 2011), extension agents (Krishnan and Patnam 2013), friends (Magnan et al. 2015), and a small set of "progressive" ones in the village (Maertens 2017).

To the best of our knowledge, however, rigorous empirical analysis of the relationship between learning from parents within the household and farmers' willingness to adopt SATs is absent from the literature. In fact, in many developing countries (notably China), with family maintaining the most intimate layer of the networks (Rühle 2012) and the cardinal importance of family ethic (Fan 2000), the young generations in a family are profoundly influenced by their parents, especially by parents' accumulated experience and related behaviors (Wu 2008). Moreover, despite the potential interdependence of SATs, very few studies have simultaneously analyzed the determinants of the adoption and intensive use intentions in rural China. Though some studies have discussed drivers of SATs adoption in Chinese certain rural areas (Xu et al. 2014; Luo et al. 2016), they have only concentrated on one or some isolated technologies with single adoption models employed. Thus, policy implications put forward based on such results are considered limited since they may fail to deal with the resource efficiency expected from farming nowadays (Kpadonou et al. 2017).

Therefore, to fill these research gaps, with unique household-level data from rural areas in Suizhou City, Tianmen City, and Xinzhou county of Wuhan City, the major rice-producing areas in Hubei Province, China, this paper attempts to employ multivariate probit model (MVP) and ordered probit model (OPM) to achieve two goals: (1) to isolate the roles of observational learning and experience-based learning through communication from parents within household from environmental factors in rice farmers' willingness to adopt SATs and their intensive use intentions so as to enrich the literature on learning mechanisms and on the adoption of SATs, and (2) to shed light on the substitution and complementation relationships between the specific SATs related to rice planting in rural China, ranging from improved seed, biopesticide, soil testing and fertilizer recommendation, straw returning technology, intercropping, and no-/mini-tillage to water-saving technology, hoping to provide significant information for agricultural policy design.

SATs in China

To address agricultural pollution and increase the efficiency of resource utilization, promoting and developing SATs in rural areas in China has been paid great attention to publicly. Typically, the major seven SATs involved in rice planting in rural China are improved seed, biopesticide, soil testing and fertilizer recommendation, straw returning technology, intercropping and no-/mini-tillage as well as water-saving technology (Wu 2017). Over the years, the Chinese government has placed the promotion and development of these SATs in rural areas at the center of its development strategy, though all these SATs have been applied in rural China for a long history. Actually, these SATs have been somehow emphasized in the national documents. In 2004, *measures for the management of subsidy funds for promoting improved rice varieties* issued by the Treasury and Agriculture Departments has clearly proposed the improvement of specific subsidy system to encourage rice farmers to adopt improved seed; in 2015, *Chinese national plan for sustainable development of agriculture (2015–2030)*, jointly issued by Agriculture Department and other national departments, has put forward that both biopesticide and soil testing and fertilizer recommendation are urgently needed to be widely applied in agricultural production in response to the serious agricultural non-point pollution, and this document has also declared that intercropping, no-/mini-tillage, and water-saving technology should be greatly promoted in rural areas to make full use of limited land and water resources; in 2011, *notice of the implementation plan for comprehensive utilization of crop straw in the twelfth five-year plan*, jointly issued by Treasury and Agriculture Departments and National Development and Reform Commission, has highlighted that it should be according to local conditions that the straw returning technology is used.

Specific to Hubei province, these SATs are also not innovative practices and they have already been applied in the rural areas for a period of history, which is affirmed by the fact that during the investigation, we found that the rice farmers surveyed all know these SATs even when they were at a much younger age. In reality, improved seed has been applied in rural Hubei province in the 1980s with some main varieties such as "E Yi 105" and "E Wan No. 5" (Yang et al. 2015), and it is in late 1980s that soil testing and fertilizer recommendation has been promoted provincially (Xu and Lu 2015); both biopesticide and straw returning technology have been provincially used in the 1990s (Gong 2002; Zhou et al. 2013), and the applications of intercropping and no-/mini-tillage have also started in the 1990s (Chen and Zeng 2016); due to drought disasters, it is early in the 1970s that water-saving technology has been promoted in rural Hubei province (Cheng 2001). In line with national policies, the local government of Hubei province has also issued a series of relevant documents. In 2018, *implementation plan for regional trial of rice varieties in Hubei province* issued by the local government has emphasized the "experimentation precedes popularization" mode to further develop improved seed step by step; in 2016, *implementation plan of demonstration and extension project for low-toxic biological pesticides in Hubei province* has stressed the importance of subsidy incentive in encouraging farmers to use biopesticide; in 2015, *implementation plan of soil testing and formulated fertilization project in Hubei province*, issued by provincial agriculture office, has put forward the specific measures, for example, providing farmers with technical training to promote and popularize soil testing and formulated fertilization in rural areas; in 2016, *guiding opinions on promoting comprehensive utilization of crop straw in Hubei province* has referred the straw returning technology as the major utilization mode of crop straw; in consistent with the national policy in 2009, *implementation norm of conservation tillage project* has been released provincially, and it underlines the measures such as providing technical training and technical demonstration to promote intercropping and no-/mini-tillage; in 2017, *overall plan of efficient water-saving irrigation in Hubei in 13th five-year* approved provincially has clearly put forward the aims of water-saving technology application.

Obviously, above documents signify that national and local governments have taken pains to expedite the adoption of these SATs in rural areas. Achieving these goals depends immensely on farmers' participation. Therefore, this paper takes a fresh look at the predictors of rice farmers' willingness to adopt these SATs and of their intensive use intentions, and attaches importance to the impacts of observational learning and experience-based learning through communication from parents in the family context in the hope of offering valuable references for promoting these SATs.

Conceptual definitions and hypotheses

Definitions of SATs

Along with agricultural development, agricultural ecological environment and resources have been severely damaged. Under this background, the thought of agricultural sustainable development has risen, and then SATs have received increasing attention from the governments and academic circles. Until now, a widely recognized definition of SATs has not yet been made. Tey et al. (2012) have defined SATs as a set of agricultural technologies for keeping harmony between nature and economy while conserving resources and increasing agriculture production in a pollution-free and nuisance-free environment. According to Wu's (2017) work, SATs involved in rice planting in China are improved seed, biopesticide, soil testing and fertilizer recommendation, straw returning technology, intercropping, no-/mini-tillage, and water-saving technology, and on this basis, these seven technologies are the focus in this study.

Specifically, improved seed is a technology with good quality that needs less input of fertilizer and pesticides than common seed, thus achieving high yields but reducing the input and lightening the pressure of the environment pollution (Sall et al. 2000); biopesticide is a new management of disease and pest that is made from eco-friendly ingredients, and it decomposes quickly so that residues could be hardly left, thereby minimizing the risk of environmental pollution or residual toxicity and enhancing food safety (Lucchi and Benelli 2018); soil testing and fertilizer recommendation is an advanced rational fertilization technology with fertilizer applied according to the needs of soil (Luo et al. 2016), and compared with chemical fertilizer, it is more environmental friendly; straw returning is an environmental friendly technology with crop straw returning to the field as fertilizer (Huang et al. 2017) rather than being burned to pollute the air; intercropping is to plant two or more crops on the same field at the same time (Wan and Lei 2018), and the application of this technology could successfully make full use of the limited land resources; no-/mini-tillage is the practice of putting seeds into the soil without/with few tillage, which could benefit farmers by reducing production costs and help to cope with land degradation by maintaining soil fertility with soil disturbance minimized (Bavorova et al. 2018); water-saving technology is a technology that makes efficient use of water resources to achieve the sustainable development of agriculture (Jabran et al. 2017). In summary, it is evident that all these SATs actually give much benefit to rice farmers, and that the adoption of these SATs is conducive to improving ecological environment and realizing agricultural sustainable development.

Hypotheses

Since Albert Bandura put forward social learning theory in 1977, this theory has been widely applied in various academic fields and gradually been enriched and then become mature through several years of development. Generally speaking, social learning not only includes the observational learning mechanism in which individuals learn from others by observing others' behaviors due to the information contained therein (Banerjee 1992; Cai et al. 2009), but also encompasses the mechanism in which individuals learn from others through direct communications (Bandura 1977; Cai et al. 2009). The former mechanism reflects the power of the behavior demonstration effect, while the latter indicates the charm of experience-based verbal exchange effect. The primary difference between observational learning and learning via communications is that social, spatial, and temporal proximity among people is critical for learning to take place or not (Langton et al. 1999; Cai et al. 2009). Specifically, learning from other people through communications needs people to be close in space, time, and social distance, whereas, observational learning could occur if the underlying decision problems faced by an individual are similar to others (Cai et al. 2009; Liu et al. 2013; Garcia and Shelegia 2018). As a consequence, efforts to expedite the adoption of targeted agricultural technologies through interpersonal communications may be effective if direct communication is prominent, but may not be effective if observational learning is the main channel of social learning.

Empirically, it has already been proved that social learning plays a central role in the popularization of new agricultural technologies (Munshi 2004). It is discussed that, not only could an individual actively learn from others by observing others' adoption behaviors, but he could also unconsciously learn from others' experience through communication (Çelen et al. 2005). In other words, he can internalize the observation of others' behaviors and information drawing from communications as part of his cognition and as his internal guidance to influence his choices (Shteynberg and Apfelbaum 2013). For example, Krishnan and Patnam (2013) have found that talking to neighbors or extension agents and observing early adopters are two important sources of the information on fertilizer and seeds farmers get that may influence their behaviors. The literature as exemplified by Maertens (2017) has also confirmed that observing the experiences of a few influential farmers and learning via discussion from others' concerns about the technology are effective measures to promote *Bacillus thuringiensis* cotton in India.

Under the family background in many developing countries, frequent contacts and exchanges have led to a relatively high degree of correlation between farmers and their parents (Ying et al. 2015), and with the prominent feature of parents maintaining their core identity, learning from farmers' parents' words and behaviors are even more likely to take place. Hence, this paper attempts to incorporate observational learning from parents' adoption behaviors and experience-based learning through communication from parents' farming experience into factors that may influence rice farmers' willingness to adopt SATs.

Observational learning

Generally speaking, observational learning refers to imitation of people of others' behaviors or actions through observation (Greer et al. 2006; Cai et al. 2009), and it illustrates that people usually choose what others choose when they are free to do as they please. In this paper, observational learning is defined as the mechanism through which parents influence rice farmers' willingness to adopt is via rice farmers learning about SATs by observing parents' behaviors of adopting SATs.

Empirically, Monfardini et al. (2013) argued that learning what behavior is appropriate in a particular context through observing the actions of others is one of the most basic forms of human cognition, since it saves energy and time, and reduces the exposure to potentially dangerous situations. Several studies have noted the significance of observational learning in predicting individual's behaviors in various contexts, such as agricultural technology adoption behaviors in Northern Mozambique (Bandiera and Rasul 2006), farmers' behaviors of fertilizer input in pineapple cultivation in Ghana (Conley and Udry 2010), and consumers' choices of different varieties sold in the market (Garcia and Shelegia 2018). Similarly, in the family context, parents' adoption behavior displays implicitly teach rice farmers which technologies are acceptable and expected in the family environment. Rice farmers observe the adoption behaviors of their parents thus having a rough idea of how to use these technologies, which may affect their adoption willingness possibly. Therefore, it can be assumed that if a rice farmer has learned from his parents by observing parents' behaviors of adopting SATs, he will maintain a positive attitude and may form an intention to adopt SATs. Thereby, it is hypothesized that:

> *H1* Learning from parents' behaviors of adopting SATs through observation positively affects rice farmers' willingness to adopt SATs.

Experience-based learning through communication

Prior studies have stated that people use the information or experience acquired from others through direct or indirect communication to guide their decision-makings (Cai et al. 2009). In this paper, experience-based learning through communication refers to the mechanism through which parents impact on rice farmers' willingness to adopt is via rice farmers learning from the amount of related experience on technologies, including traditional and sustainable agricultural technologies, either negative or positive, expressed verbally by their parents.

Empirically, previous literature has analyzed the role played by learning via communication in personal decision-makings. For example, Ameri et al. (2016) found that consumers extract product information directly from others' opinions via exchange, thus influencing their consumption choices; Banerjee and Fudenberg (2004) emphasized that learning from the old generation via communication acts as a stimulus to the identical decisions made by the young generation of agents. As Cai et al. (2009) note, learning through communication requires individuals to be close in time, space, and social distance. In view of family background, since rice farmers are close to their parents both in time, space, and social distance due to the prominent family-focused feature in many developing countries, parents are those that rice farmers often come in contact with and frequently communicate with, and under such circumstance, experience-based learning via communication is more likely to happen. Therefore, it can be assumed that if a rice farmer has learned from his parents' experience via communication, he will internalize the experience learned from his parents as the guide of his intentions to adopt SATs. Thereby, it is hypothesized that:

> *H2* Learning from parents' farming experience through communication significantly affects rice farmers' willingness to adopt SATs.

Data and methodology

Data collection

The data used for this study is from a household survey of rice farmers conducted in Suizhou City, Tianmen City, and Xinzhou County of Wuhan City in Hubei province, China, between July and August in 2016, and the geographical distribution of these three regions is seen in Fig. 1.

These three regions offer an interesting case study for discussing the concerns at stake. On the one hand, the hilly landform of Suizhou City, the plain landform of Tianmen City, and the mountainous landform of Xinzhou County cover the basic topographic features of Hubei province; on the other hand, regions surveyed are areas dominated by rice growing in Hubei province: all of these reasons make these regions surveyed typical representatives of this province. In sum, a random sampling strategy was used to collect data, appropriately owing to the representativeness of areas with varying rice potential and with main landforms. Yet it should be noted that results drawn from our study are from two specific cities and a specific county in China and may or may not represent the entire body of rice farmers in rural China.

Prior to the survey, a pre-survey was conducted, which leads to the revision of some of the interview questions. A structured questionnaire designed for this study was used and it mainly consists of five parts: The first part measured basic characteristics including individual features (e.g., gender, age, educational attainment) and household as well as farm characteristics (e.g., number of household labor, on-farming income, land acreage, land quality). The second part measured respondents' perceptions of the environmental protection function and risk of SATs. The third part measured the impacts of neighbors, cadres, and subsidy policy at the village level on respondents' willingness to adopt SATs. The fourth part measured respondents' observational learning from parents' behaviors of adopting SATs and experience-based learning through communication from parents' farming experience including that on SATs. The final part measured respondents' willingness to adopt SATs. In this section, seven SATs related to rice planting (including improved seed, biopesticide, soil testing and fertilizer recommendation, straw returning technology, intercropping, no-/mini-tillage and water-saving technology) are given to respondents, and they were required to choose those that they are willing to adopt.

Face-to-face interviews were supervised by 6 doctoral students and 20 postgraduates who had rich rural research experience and were professionally trained before the formal survey was carried out. With the random sampling strategy used and the joint endeavors from the research team and respondents, 634 questionnaires were obtained. Those with antilogy and key information missing were excluded, and eventually 550 samples were valid for this study. The general effective rate is 86.75%. The valid samples of Suizhou City, Tianmen City, and Xinzhou County are 175, 202, and 173, respectively, accounting for 31.82%, 36.73%, and 31.45% of the total valid number accordingly.

Descriptive statistics

Figure 2 shows the basic situation of observational learning from parents' adoption behaviors and experience-based learning through communication from parents' farming experience in the areas surveyed. It can be observed that only a small proportion (11%) of the total sample have observational

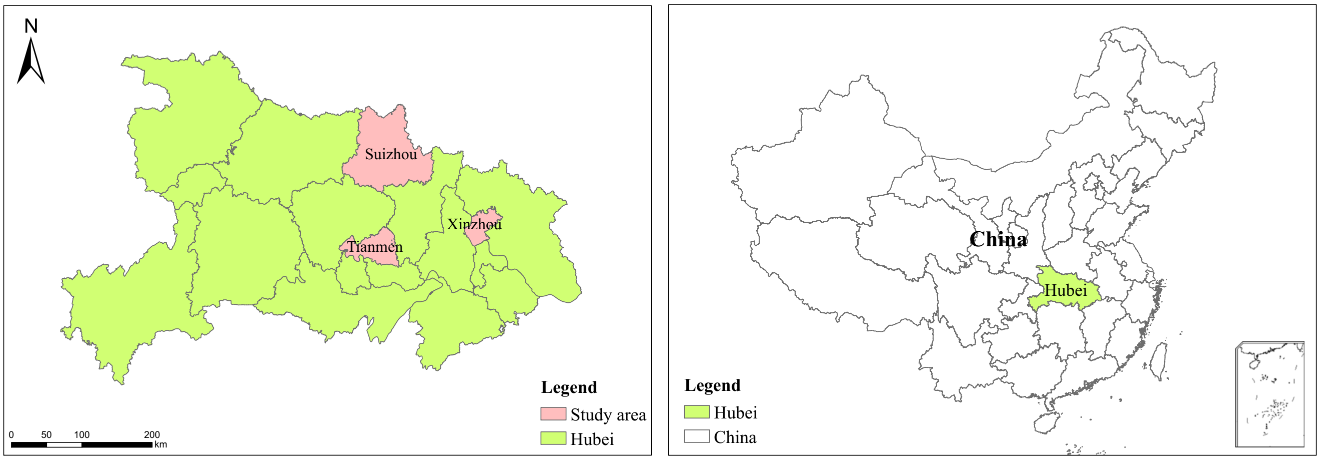


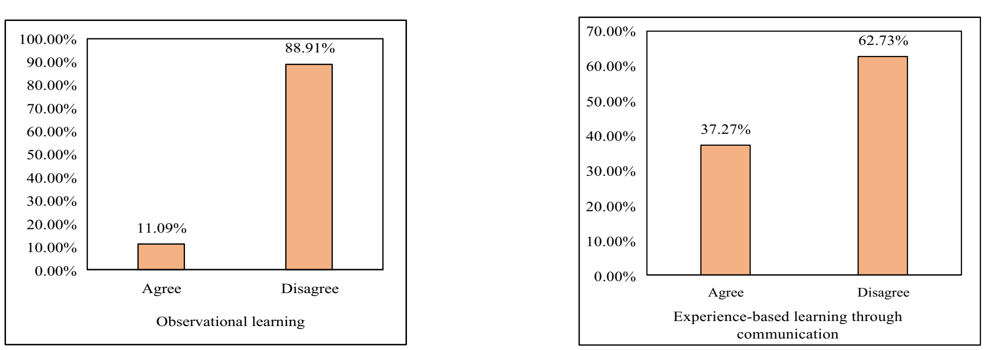
Fig. 1 Distribution of areas surveyed

learning from their parents' behaviors of adopting SATs, while those who do not have this kind of learning account for 88.91%. In addition, those who have experience-based learning through communication account for 37.27%, less than the proportion (62.73%) of those who do not have this kind of learning.

Figure 3 is about the proportions of respondents' willingness to adopt the seven types of SATs. Through the analyses of the data surveyed, it is noted that, with these seven types of SATs taken into consideration, proportions of respondents' willingness to adopt them separately are quite different. Specifically, improved seed is quite popular with respondents on the grounds that 65.27% are willing to adopt it. About half of the respondents (50.91%) are willing to adopt biopesticide, followed by the proportion (44.73%) of those who are willing to adopt soil testing and fertilizer recommendation. Respondents who are willing to adopt water-saving technology, straw returning technology, and no-/mini-tillage account for 40.18%, 36.00%, and 11.09% of the total sample respectively. Only 7.45% are willing to adopt intercropping. It should be noted that the sum of the proportions of respondents' willingness to adopt the seven types of SATs is greater than 100%, since respondents are required to choose one type or some types of SATs as they want.

Table 1 presents the intensity of rice farmers' adoption intentions. It can be observed that the number of SATs that rice farmers are willing to adopt ranges from one to five. Specifically, 94.91% of rice farmers are willing to adopt one to three SATs, whereas, only 5.09% are willing to adopt four or five SATs, and the possible reason is that, with low family incomes and small-scale land management, rice farmers are often willing to adopt limited number of SATs with the consideration of cost and benefit (Barrett et al. 2002). These descriptive analyses indicate that much more efforts are needed to figure out the correlations between these SATs and to further explore the factors influencing the intensity of rice farmers' adoption intentions. Hence, this paper attempts to reveal the relationships between these SATs and to examine the impacts of observational learning and experience-based learning through communication in the family context on rice farmers' intensive use intentions so as to give full play to the roles of the potentially synergistic complementary or substitution effects in promoting the agricultural sustainable development.

Fig. 2 Observational learning and experience-based learning through communication (N = 550)



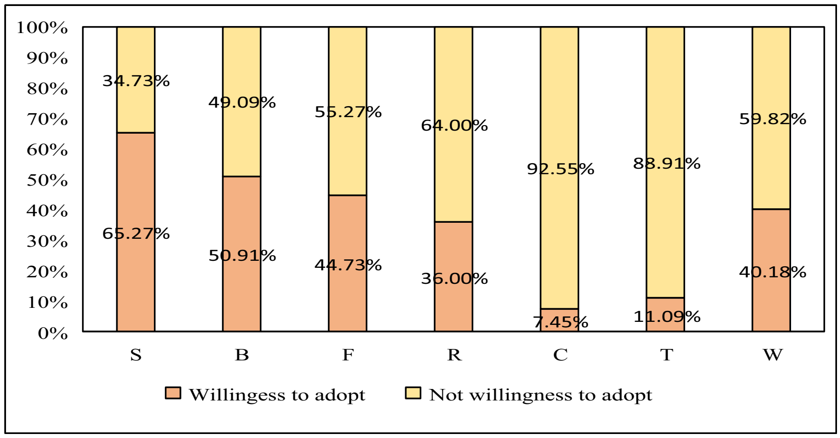


Fig. 3 Proportions of respondents' willingness to adopt seven SATs ($N = 550$). This figure presents the proportions of respondents' willingness to adopt seven SATs, namely, improved seed (S), biopesticide (B), soil testing and fertilizer recommendation (F), straw returning technology (R), intercropping (C), no-/mini-tillage (T), and water-saving technology (W)

Model selection

In general, rice farmers' willingness to adopt SATs is quite complex on the grounds that it is often affected by multiples factors (Baerenklau and Knapp 2007). For a SAT, it is a typical binary choice in that rice farmers simply have two options, namely, willingness to adopt it or to not adopt it. However, SATs are multiple, and rice farmers are often willing to adopt some of them simultaneously with the consideration of distinct agricultural production constraints, that is, their willingness to adopt is inherently multivariate. In this context, certain potentially unobserved disturbances would probably affect rice farmers' willingness to adopt some SATs simultaneously. So binary Probit model employed would exclude useful information about interdependent and simultaneous adoption decisions (Dorfman 1996), and biased estimates would be probably generated in those studies which isolate farmers' adoption of one SAT from another or neglect the importance of cross-technology correlation effects (Teklewold et al. 2013). Therefore, in this paper, MVP and OPM are employed to particularly analyze the effects of observational learning and experience-based learning through communication in the family context on rice farmers' willingness to adopt seven SATs and on their intensive use intentions, respectively.

First, MVP is used to explore the influences of observational learning and experience-based learning through communication on rice farmers' willingness to adopt seven SATs, including improved seed (*S*), biopesticide (*B*), soil testing and fertilizer recommendation (*F*), straw returning technology (*R*), intercropping (*C*), no-/mini-tillage (*T*), and water-saving technology (*W*). This model has already been verified to allow for the potential correlations between unobserved disturbances and the relationships between the willingness to adopt different technologies (Belderbos et al. 2004) as well as the correlations between error terms of different equations (Greene 2008). Specifically, this model contains a number of binary variables and can be given by:

$$y^* = a_0 + \sum_i a_i x_i + \sum_j \beta_j control_j + \varepsilon \quad (1)$$

$$y = \begin{cases} 1 \ if \ y^* > 0 \\ 0 \ otherwise \end{cases} \quad (2)$$

where y^* denotes the latent variable; x_i denotes the core explanatory variables; i denotes the number of the core explanatory variables; $control_i$ denotes control variables; j denotes the number of control variables. Thus if $y^* > 0$, $y = 1$, which denotes that the rice farmer surveyed is willing to adopt

Table 1 Intensity of rice farmers' willingness to adopt SATs

Number of SATs	Number of those who are willing to adopt	Percentage of those who are willing to adopt
0	0	0.00
1	36	6.55
2	203	36.91
3	283	51.45
4	25	4.55
5	3	0.54
6	0	0.00
7	0	0.00
Total	550	100

SATs; α_i, β_i denote the estimation parameters; ε denotes the random errors, and they jointly follow a multivariate normal distribution (MVN) with zero conditional mean, where $\varepsilon \sim MVN(0, \psi)$ and the symmetric covariance matrix ψ is given by:

$$\psi = \begin{Bmatrix} 1 & \rho_{SB} & \rho_{SF} & \rho_{SR} & \rho_{SC} & \rho_{ST} & \rho_{SW} \\ \rho_{BS} & 1 & \rho_{BF} & \rho_{BR} & \rho_{BC} & \rho_{BT} & \rho_{BW} \\ \rho_{FS} & \rho_{FB} & 1 & \rho_{FR} & \rho_{FC} & \rho_{FT} & \rho_{FW} \\ \rho_{RS} & \rho_{RB} & \rho_{RF} & 1 & \rho_{RC} & \rho_{RT} & \rho_{RW} \\ \rho_{CS} & \rho_{CB} & \rho_{CF} & \rho_{CR} & 1 & \rho_{CT} & \rho_{CW} \\ \rho_{TS} & \rho_{TB} & \rho_{TF} & \rho_{TR} & \rho_{TC} & 1 & \rho_{TW} \\ \rho_{WS} & \rho_{WB} & \rho_{WF} & \rho_{WR} & \rho_{WC} & \rho_{WT} & 1 \end{Bmatrix} \quad (3)$$

where the off-diagonal elements in the covariance matrix denote the unobserved correlations between the stochastic components of different SATs that rice farmers are willing to adopt. Specifically, if the value of the off-diagonal element in the covariance matrix is less than 0 and statistically significant, the SATs that rice farmers are willing to adopt are substitutes; while if the value of the off-diagonal element in the covariance matrix is over 0 and statistically significant, the SATs that rice farmers are willing to adopt are complementarities.

Second, considering that the influences of observational learning and experience-based learning through communication on rice farmers' willingness to adopt a single SAT may be different from that on their willingness to adopt many SATs, OPM is used to distinguish the differences in these kinds of influences. Following the approach of Teklewold et al. (2013), the number of SATs that rice farmer is willing to adopt, as a count variable, is used as the intensity of adoption intentions. Moreover, since the probability of rice farmers' willingness to adopt the first SAT may differ from that of their willingness to adopt the second and the third one since they may already gain the eco-friendly attributes of the first SAT that they are willing to adopt, so the number of SATs that rice farmers are willing to adopt is regarded as an ordinal variable, and then OPM is used because this model is proper to evaluate the correlation between the ordinal dependent variable and relevant independent variables (Teklewold et al. 2013).

Table 2 presents the descriptive summary of dependent variables, key independent variables, and control independent variables. Based on the purpose of this paper, the key independent variables are observational learning and experience-based learning through communication. In addition, considering that some factors may also influence rice farmers' willingness to adopt seven SATs, some other independent variables are set as control variables in this paper, such as individual characteristics (including gender, age, and educational attainment), household characteristics (including on-farming income and number of labor), farm characteristics (including land acreage and land fertility) and personal perceptions (including perception of environmental protection and risk

Table 2 Descriptive summary of variables used in estimations (N = 550)

Variable name	Variable description	Sample mean	Standard deviation
Dependent variables			
Improved seed	Discrete variable = 1 if respondent is willing to adopt improved seed	0.653	0.476
Biopesticide	Discrete variable = 1 if respondent is willing to adopt biopesticide	0.509	0.500
Soil testing and fertilizer recommendation	Discrete variable = 1 if respondent is willing to adopt soil testing and fertilizer recommendation	0.447	0.497
Straw returning	Discrete variable = 1 if respondent is willing to adopt straw returning	0.360	0.480
Intercropping	Discrete variable = 1 if respondent is willing to adopt intercropping	0.075	0.263
No-/mini-tillage	Discrete variable = 1 if respondent is willing to adopt no-/mini-tillage	0.111	0.314
Water-saving technology	Discrete variable = 1 if respondent is willing to adopt water-saving technology	0.402	0.490
Key independent variables			
Observational learning	Discrete variable = 1 if respondent believes that he has learned from parents' behaviors of adopting SATs through observation	0.111	0.314
Experience-based learning through communication	Discrete variable = 1 if respondent believes that he has learned from parents on farming experience especially on SATs through communication	0.373	0.484
Control independent variables			
Individual and household characteristics			
Gender	Discrete variable = 1 if respondent is male	0.933	0.250
Age	Age of respondent (year)	56.236	9.651
Educational attainment	Educational attainment of respondent (year)	7.074	3.134
On-farming income	Household total on-farming income in 2015 (10,000 yuan)	1.145	1.076
Number of labor	Number of labors in household in 2015	2.995	1.378
Farm characteristics			
Land acreage	Household land acreage in 2015 (hectare)	0.445	0.328
Land fertility	Discrete variable = 1 if soil fertility ranks above average; discrete variable = 0 if soil fertility ranks below average	0.349	0.477

Table 2 (continued)

Variable name	Variable description	Sample mean	Standard deviation
Personal perceptions			
Perception of environmental protection	Discrete variable = 1 if respondent has a strong sense of environmental protection	0.825	0.380
Risk perception	Discrete variable = 1 if respondent thinks there is much more risk to adopt SATs	0.567	0.495
Influence from social network and institution			
Neighbor's influence	Discrete variable = 1 if respondent believes that neighbors have an important impact on his adoption of SATs	0.509	0.500
Village cadre's influence	Discrete variable = 1 if respondent believes that village cadres have an important impact on his adoption of SATs	0.731	0.443
Subsidy's influence	Discrete variable = 1 if respondent believes that government subsidies have an important impact on his adoption of SATs	0.618	0.486

Source: Authors' summary of the survey sample

perception), as well as the influences from social network and institution (including neighbor's influence, village cadre's influence and subsidy's influence).

Empirical results and discussions

Estimation results of MVP

With Stata 13 software, rice farmers' willingness to adopt seven SATs is primarily estimated by MVP. The covariance matrix of the regression equation is shown in Table 3.

It can be observed that X^2 of the model is 229.407, and that prob > chi^2 is significant at the 1% level, indicating that correlation does exist between the random perturbations of each equation. Therefore, MVP fits the data well in this study. It is known from the table that 13 covariances are statistically significant, indicating that rice farmers' willingness to adopt one of the seven SATs is truly influenced by their willingness to adopt another one.

Specifically, improved seed is a substitute for biopesticide, straw returning, and water-saving technology, and it is possibly because, apart from the high yielding attribute, improved seed also has the distinctive characteristics of saving water or drought and insect resistances, and the use of this technology does not need that much input (Sall et al. 2000); biopesticide is a substitute for straw returning, intercropping, no-/mini-tillage, and water-saving technology, and the possible explanation is that, to a certain extent, biopesticide could replace the proper use of these eco-friendly technologies which could reduce insect pest population (Lucchi and Benelli 2018); soil testing and fertilizer recommendation is a substitute for straw returning, intercropping, no-/mini-tillage, and water-saving technology, and the possible reason is that soil testing and fertilizer recommendation is enough to deal with the nutrients needed by crops (Luo et al. 2016), thus substituting other relevant SATs to a certain extent; straw returning is a substitute for water-saving technology, and it is possible because straw returning could help the conservation of soil moisture and nutrient (Huang et al. 2017), thus substituting the use of water-saving technology; while intercropping is complementary with no-/mini-tillage, and one possible explanation could be that, high crop productivity of intercropping just complements with the uncertainty regarding the economic outcome of no-/mini-tillage while all of these technologies contributing to soil sustainability (Wan and Lei 2018; Bavorova et al. 2018).

The MVP model regression results of rice farmers' willingness to adopt SATs are presented in Table 4. It can be observed that, with Wald chi^2 = 383.130 (p = 0.000 < 1), the model is well fit with the data. Results reveal that observational learning and experience-based learning through communication do have significant impacts on rice farmers' willingness to adopt some types of SATs. Detailed analysis is stated as follows.

As we hypothesized, estimation results reveal that observational learning is significant at the 5%, 5%, 5%, and 1% significance levels in the biopesticide, soil testing and fertilizer recommendation, no-/mini-tillage, and water-saving technology equations, respectively, and that the coefficients are all positive. These results indicate that, with other conditions unchanged, compared to other rice farmers, those who have observational learning from their parents are more willing to adopt biopesticide, soil testing and fertilizer recommendation, no-/mini-tillage, and water-saving technology. These findings just affirm the conclusions drawn from previous studies that the behaviors of others observed could influence one's intentions or behaviors when they face the similar underlying decision problems (Cai et al. 2009; Chen et al. 2009). Specifically in the family context, rice farmers and their parents are often in face of the similar problems in agricultural production due to the close linkages between their farmlands (Liang et al. 2015). Therefore, observing parents' behaviors of adopting SATs could make these SATs more salient than other alternatives, thereby enhancing rice farmers' adoption intentions.

As we hypothesized, MVP model regression results show that experience-based learning through communication significantly influences rice farmers' willingness to adopt some SATs, whereas this kind of influence is quite complicated. Specific analysis is stated as follows.

Table 3 The covariance matrix of MVP regression equation ($N = 550$)

Types of SATs	Improved seed	Biopesticide	Soil testing and fertilizer recommendation	Straw returning	Inter cropping	No-/mini-tillage	Water-saving technology
Improved seed	–	–	–	–	–	–	–
Biopesticide	– 0.157**(0.-068)	–	–	–	–	–	–
Soil testing and fertilizer recommendation	− 0.017 (0.067)	0.095 (0.071)	–	–	–	–	–
Straw returning	− 0.258*** (0.067)	− 0.209*** (0.065)	− 0.232*** (0.066)	–	–	–	–
Inter cropping	0.158 (0.101)	− 0.319*** (0.092)	− 0.219** (0.099)	-0.007 (0.090)	–	–	–
No-/mini- tillage	− 0.119 (0.094)	− 0.307*** (0.085)	− 0.220** (0.086)	− 0.105 (0.084)	0.185* (0.107)	–	–
Water-saving technology	− 0.332*** (0.068)	− 0.236*** (0.069)	− 0.282*** (0.066)	− 0.178** (0.071)	− 0.123 (0.087)	0.093 (0.082)	–
X^2	229.407						
Prob > chi^2	0.000						
Likelihood ratio test	$\rho_{21} = \rho_{31} = \rho_{41} = \rho_{51} = \rho_{61} = \rho_{71} = \rho_{32} = \rho_{42} = \rho_{52} = \rho_{62} = \rho_{72} = \rho_{43} = \rho_{53} = \rho_{63} = \rho_{53} = \rho_{63} = \rho_{73} = \rho_{54} = \rho_{64} = \rho_{74} = \rho_{65} = \rho_{75} = \rho_{76} = 0$						

Standard deviations are in parentheses. ***, **, and * indicate the significance at the 1%, 5%, and 10% levels respectively. Numbers in this table are round up and round down numbers

(1) Experience-based learning through communication is significant at the 5%, 5%, and 1% significance levels in improved seed, soil testing and fertilizer recommendation, and intercropping equations, respectively, and the coefficients are all negative. These findings indicate that, with other conditions unchanged, compared to other rice farmers, those who have experience-based learning through communication from parents' farming experience are less willing to adopt improved seed, soil testing and fertilizer recommendation, and intercropping. The possible explanations are that, on the one hand, improved seed is often more expensive than common seed (Sall et al. 2000); on the other hand, the application of intercropping requires additional management skills, and the use of soil testing and fertilizer recommendation needs much more time, skills, energy, and cost than other fertilization treatments (Luo et al. 2016). Whereas in many developing countries, the level of rice farmers' income is relatively low, and their money and time are often allocated to cost-saving and time-saving agricultural activities (Davis and Wen 2011). Thus, parents' farming experience probably underlines the disadvantages of improved seed, soil testing and fertilizer recommendation, and intercropping. As a result, influenced by parents' negative farming experience on these three SATs through communication, rice farmers are less willing to adopt them.

(2) Experience-based learning through communication is significant at the 1% and 5% significance levels in biopesticide and water-saving technology equations, respectively, and the coefficients are all positive. These findings indicate that, with other conditions unchanged, compared to other rice farmers, those who have experience-based learning through communication from their parents are more willing to adopt biopesticide and water-saving technology. Some of the reasons that might contribute to these scenarios are that, on the one hand, biopesticide maintains less harmful substances especially to human health than traditional chemical pesticides which are associated with long-term health risks (Gilden et al. 2010); on the other hand, since moderate droughts have occurred frequently in Hubei province since the mid-twentieth centaury (Cheng 2001), the use of water-saving technology has helped parents make through the droughts. Therefore, parents' farming experience probably stresses the advantages of biopesticide and water-saving technology. As a consequence, influenced by parents' positive experience on these two SATs through communication, rice farmers are more willing to adopt them.

Unexpectedly, the regression results show that neither of observational learning and experience-based learning through communication has a significant influence on rice farmers' willingness to adopt straw returning. This indicates that observational learning from parents' behaviors of adopting sustainable technologies and experience-based learning through communication from parents' farming experience are not crucial factors that influence rice farmers' willingness to adopt straw returning. The possible reason is that, in China, the large-scale extension of the mechanization of straw returning starts relatively late, and so parents' adopting behaviors and farming experience are not enough to significantly influence rice farmers' adoption intentions.

Table 4 Estimation results from the MVP model ($N = 550$)

Variables	Improved seed	Biopesticide	Soil testing and fertilizer recommendation	Straw returning	Intercropping	No-/mini-tillage	Water-saving technology
Key independent variables							
Observational learning	− 0.096 (0.180)	0.420** (0.201)	0.479** (0.187)	− 0.263 (0.191)	0.176 (0.281)	0.414** (0.212)	0.714*** (0.182)
Experience-based learning through communication	− 0.277** (0.117)	0.705*** (0.119)	− 0.232** (0.118)	0.117 (0.119)	− 0.620*** (0.206)	0.212 (0.147)	0.310** (0.120)
Control independent variables							
Individual and household characteristics							
Gender	− 0.297 (0.239)	0.108 (0.258)	0.891*** (0.268)	0.074 (0.246)	− 0.012 (0.287)	− 0.691** (0.271)	− 0.734*** (0.264)
Age	0.009 (0.006)	− 0.004 (0.006)	− 0.000 (0.006)	− 0.003 (0.006)	− 0.018** (0.009)	0.005 (0.008)	− 0.001 (0.006)
Educational attainment	0.004 (0.020)	0.018 (0.020)	0.038* (0.021)	− 0.016 (0.020)	− 0.052* (0.027)	0.012 (0.026)	0.006 (0.021)
On-farming income	− 0.177** (0.073)	0.016 (0.062)	0.057 (0.067)	− 0.018 (0.066)	0.064 (0.125)	− 0.328*** (0.117)	− 0.021 (0.066)
Number of labor	0.081* (0.044)	0.079* (0.042)	0.016 (0.042)	− 0.058 (0.041)	0.093 (0.063)	0.067 (0.050)	0.001 (0.042)
Farm characteristics							
Land acreage	− 0.084 (0.215)	− 0.221 (0.214)	− 0.072 (0.223)	0.385* (0.211)	− 1.245** (0.531)	0.526* (0.309)	0.106 (0.228)
Land fertility	0.106 (0.117)	0.095 (0.120)	− 0.664*** (0.122)	0.074 (0.118)	0.141 (0.169)	− 0.039 (0.153)	0.084 (0.123)
Personal perceptions							
Perception of environmental protection	0.143 (0.150)	0.040 (0.147)	− 0.017 (0.149)	− 0.243 (0.149)	− 0.463** (0.199)	0.172 (0.205)	0.146 (0.154)
Risk perception	− 0.295** (0.119)	0.097 (0.118)	0.087 (0.117)	− 0.396*** (0.118)	0.087 (0.150)	− 0.053 (0.153)	0.228* (0.122)
Influence from social network and institution							
Neighbor's influence	0.219* (0.118)	0.314*** (0.117)	− 0.225* (0.116)	0.172 (0.118)	− 0.106 (0.179)	− 0.111 (0.141)	− 0.133 (0.121)
Village cadre's influence	0.082 (0.135)	− 0.098 (0.133)	0.121 (0.133)	− 0.103 (0.133)	− 0.133 (0.190)	0.323** (0.164)	− 0.015 (0.138)
Subsidy's influence	− 0.015 (0.119)	0.246** (0.119)	0.312*** (0.120)	0.223* (0.123)	0.393** (0.181)	0.216 (0.158)	− 0.159 (0.124)
Constant	− 0.455 (0.461)	− 0.783 (0.482)	− 1.262** (0.497)	0.076 (0.474)	0.329 (0.605)	− 1.631*** (0.614)	0.133 (0.476)
Log likelihood	− 1903.702						
Wald chi^2 (98)	383.130						
Prob > chi^2	0.000						

Standard deviations are in parentheses. ***, **, and * indicate the significance at the 1%, 5%, and 10% levels respectively. With Stata 13 software, the mvprobit command is performed with "robust" added. Numbers in this table are round up and round down numbers after robust regression of the survey data

Estimation results of OPM

As reported in the previous section, the number of SATs that rice farmers are willing to adopt varies. To investigate the impacts of observational learning and experience-based learning through communication on rice farmers' intensive use intentions, OPM model is employed with the marginal effects also estimated. Estimation results are all shown in Table 5.

It can be observed that Wald chi^2 (14) = 124.650 ($p \geq 0.000$), showing that the joint test of all slope coefficients equal to zero is rejected. According to column 1 in Table 5, observational learning and experience-based learning through communication are all significant at the 1% significance level, and the coefficients are all positive, indicating that, with other conditions unchanged, both observational learning from parents and experience-based learning through communication from parents in the family context could contribute to strengthening rice farmers intensive use intentions. These findings are just in line with the results reported in the previous section which confirm the significant impacts of observational learning and experience-based learning through communication on rice farmers' willingness to adopt some SATs.

With respect to the results of marginal effects of both observational learning and experience-based learning through communication, it can be observed that, for $j \leq 2$ (columns 2 and 3), the signs of the marginal effects' coefficients are inconsistent with those of the estimation results in column 1, while for $j \geq 3$ (columns 4, 5, and 6), the signs of the coefficients are consistent with those of the estimation results in column 1. These findings may indicate that the influence of observational learning on rice farmers who are willing to adopt two and less SATs is quite different from that on those who are willing to adopt three and more SATs, which is also true for the influence of experience-based learning through communication.

For the aim to promote rice farmers' intensive use intentions, the probability of rice farmers' willingness to adopt three and more SATs is particularly discussed. Specifically,

Table 5 Estimation results from the OPM model

Variables	Estimation results (N = 550)	Marginal effects				
		dy/dx (j = 1)	dy/dx (j = 2)	dy/dx (j = 3)	dy/dx (j = 4)	dy/dx (j = 5)
Key independent variables						
Observational learning	1.103*** (0.182)	− 0.126*** (0.025)	− 0.254*** (0.042)	0.286*** (0.049)	0.080*** (0.016)	0.014* (0.007)
Experience-based learning through communication	0.362*** (0.106)	− 0.041*** (0.013)	− 0.083*** (0.024)	0.094*** (0.026)	0.026*** (0.009)	0.005* (0.003)
Control independent variables						
Individual and household characteristics						
Gender	0.023 (0.194)	− 0.003 (0.022)	− 0.005 (0.045)	0.005 (0.050)	0.002 (0.014)	0.000 (0.002)
Age	− 0.007 (0.005)	0.001 (0.001)	0.002 (0.001)	− 0.002 (0.001)	− 0.000 (0.000)	− 0.000 (0.000)
Educational attainment	0.006 (0.018)	− 0.001 (0.002)	− 0.001 (0.004)	0.002 (0.005)	0.000 (0.001)	0.000 (0.000)
On-farming income	− 0.148* (0.057)	0.017** (0.007)	0.034** (0.013)	− 0.038** (0.015)	− 0.011** (0.004)	− 0.002 (0.001)
Number of labor	0.123*** (0.036)	− 0.014*** (0.004)	− 0.028*** (0.008)	0.032*** (0.009)	0.009*** (0.003)	0.002* (0.001)
Farm characteristics						
Land acreage	0.029 (0.176)	− 0.003 (0.020)	− 0.007 (0.040)	0.007 (0.046)	0.002 (0.013)	0.000 (0.002)
Land fertility	− 0.179* (0.107)	0.021 (0.013)	0.041* (0.024)	− 0.047* (0.028)	− 0.013 (0.008)	− 0.002 (0.002)
Personal perceptions						
Perception of environmental protection	0.061 (0.130)	− 0.007 (0.015)	− 0.014 (0.030)	0.016 (0.034)	0.004 (0.009)	0.001 (0.002)
Risk perception	− 0.181* (0.105)	0.021* (0.012)	0.042* (0.024)	− 0.047* (0.027)	− 0.013 (0.008)	− 0.002 (0.002)
Influence from social network and institution						
Neighbor's influence	0.232** (0.104)	− 0.027** (0.012)	− 0.053** (0.024)	0.060** (0.027)	0.017** (0.008)	0.003 (0.002)
Village cadre's influence	− 0.034 (0.112)	0.004 (0.013)	0.008 (0.026)	− 0.009 (0.029)	− 0.002 (0.008)	− 0.000 (0.001)
Subsidy's influence	0.496*** (0.111)	− 0.057*** (0.015)	− 0.114*** (0.024)	0.129*** (0.028)	0.036*** (0.009)	0.006* (0.004)
Wald chi^2 (14)	124.650					
Prob > chi^2	0.000					
Pseudo R^2	0.108					
Log likelihood	− 518.631					

Standard deviations are in parentheses. ***, **, and * indicate the significance at the 1%, 5%, and 10% levels respectively. With Stata 13 software, the oprobit command is performed with "robust" added. Numbers in this table are round up and round down numbers after robust regression of the survey data for rice farmers who have observational learning, the probability of their willingness to adopt three and more SATs would increase 38%, and for those who have experience-based learning through communication, the probability of their willingness to adopt three and more SATs would increase 12.5%. These findings indicate that observational learning is much more powerful than experience-based learning through communication in increasing the probability of rice farmers' willingness to adopt three and more SATs[1], which is just consistent with the traditional wisdom, saying that "actions speak louder than words" (Liu 2006).

Conclusions and policy implications

Based on the data obtained from field survey on rice farmers in Hubei province, China, this study contributes to the literature on social learning and SAT adoption by examining and identifying the impacts of observational learning and experience-based learning through communication from parents in the family context on rice farmers' willingness to adopt seven SATs and on their intensive use intentions. Methodologically, both MVP and OPM are used. Overall, results from our empirical model provide strong evidence for observational learning and experience-based learning through communication from parents in rice farmers' willingness to adopt SATs. Specifically, three interesting findings and related policy implications are stated as follows.

First, complementary and substitute relations do exist between rice farmer' willingness to adopt one SAT and another. Besides, the proportions of rice farmers' willingness to adopt some SATs (such as intercropping and no-/mini-tillage) are generally low, and few rice farmers are willing to adopt five or more SATs. These findings are just consistent with the conclusions drawn from previous studies (Luo et al. 2014, 2016). The policy implication is that policy makers and implementers should take the correlations between one SAT and other SATs into consideration when they design and initiate the strategies of promoting SATs in rural areas on the grounds that policy changes aiming to influence one SAT could have spillover effects to other SATs. More specifically, efforts need to be made to encourage rice farmers to adopt complementary SATs simultaneously, such as intercropping and no-/mini-tillage, and to adopt one of SATs that have substitute relations, thus giving full play to the synergy complementary and substitute effects of these SATs and truly improving rice farmers intensive use intentions.

Second, observational learning in the family context not only has a pronounced positive effect on rice farmers' willingness to adopt biopesticide, soil testing and fertilizer recommendation, no-/mini-tillage, and water-saving technology, but also greatly increases the probability of rice farmers' willingness to adopt three and more SATs. This is a surprising and significant finding that helps us to understand the factors influencing rice farmers' willingness to adopt SATs. From a policy perspective, it suggests that measures, such as providing subsidies and stepping up publicity efforts, should be taken to encourage rice farmers to learn from their parents' behaviors of adopting SATs through observation, and by this way, the effect of observational learning within the household level could be fully brought into play in promoting the popularization of SATs.

Third, experience-based learning through communication in the family context significantly and negatively influences rice farmers' willingness to adopt improved seed, soil testing and fertilizer recommendation, and intercropping, but positively affects their willingness to adopt biopesticide and water-saving technology as well as their intentions to adopt three and more SATs. These results have significant policy implications. Policy makers should begin with policy incentives to dialectically guide rice farmers to communicate with their parents selectively on the farming experience of some SATs, and be aware of the negative role of experience-based learning through communication in the family context on rice farmers' willingness to adopt some SATs when designing policies to encourage households to construct a comfortable atmosphere of mutual communication. By this way, the aim to strengthen the promotion and application of SATs in rural areas by advocating experience-based learning through communication in the family context could be truly achieved.

Admittedly, although a comprehensive study is conducted in this paper, there are some limitations that should be noted, which also casts lights on future research directions. First, owing to the limitation of the data at hand, this study only estimates the impacts of observational learning and experience-based learning through communication within household on rice farmers' willingness to adopt SATs in 2016, but that how the dynamic effects of observational learning and experience-based learning through communication in the family context would change over the years is not investigated. For future studies with panel data used, it would be very interesting to make a thorough analysis of the influence trends of observational learning and experience-based learning through communication from parents on rice farmers' willingness to adopt SATs. Second, due to the limitation of the data at hand, we are unable to have delved deeper in the research on believes and these influencing rice farmers' willingness. A belief, as a construction of an idea, has the ability to "withstand" scientific knowledge acquired through classical education processes. Therefore, if data is available, future research is warranted to examine how believes could exert an influence rice farmers' willingness to adopt SATs.

[1] It should be noted that to improve intensive use intentions of rice farmers who adopt two and less SATs, special measures are needed to be taken.

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