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Internet-Based Information Acquisition, Technical Knowledge and Farmers' Pesticide Use: Evidence from Rice Production in China

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Abstract: The overuse of pesticides has led to serious ecological and environmental degradation, largely due to the lack of effectiveness of agricultural-extension services. In recent years, an increasing number of farmers have tended to acquire technical information from the Internet. In this context, the present study analyzes the impact of Internet-based information acquisition on pesticide use and the mediating role of farmers' technical knowledge. For this purpose, the treatment-effects model and survey data covering 1113 rice farmers in Guizhou, Hubei, Jiangsu, and Zhejiang provinces in China were utilized. The results indicate that Internet-based information acquisition could significantly reduce the intensity of pesticide use by 2.036 kg/ha, accounting for the self-selection issue. Further analysis illustrates that farmers' technical knowledge plays a significant mediating role in the negative impact of Internet-based information acquisition on pesticide-use intensity. In addition, the impacts of Internet-based information acquisition on pesticide-use intensity are heterogeneous across different education levels or rice-sown areas. Thus, the present study suggests that efforts should be made to accelerate the construction of rural information infrastructure networks to broaden smallholder farmers' access to technical information from the Internet platforms, promote "Internet plus" agricultural-extension services, and improve farmers' skills in using the Internet.

Keywords: Internet; information acquisition; technical knowledge; pesticide use

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1. Introduction

Chinese agricultural production has long relied on chemical inputs such as pesticides. Pesticides have played an important role in reducing food production losses caused by pest outbreaks and have contributed to the increase in agricultural productivity. However, the overuse of pesticides has resulted in serious environmental issues, including agricultural non-point-source pollution, and concerns about the quality and safety of agricultural products, which have attracted widespread attention from consumers, governments, and related sectors [1]. In recent years, society has attached more attention to the green development of agriculture. Meanwhile, the contradiction between pesticide use and the green development of agriculture has become prominent [2]. To address the problem of pesticide overuse, the Chinese government has taken multifaceted actions to reduce pesticide use. Specifically, more efforts have been made to provide farmers with agricultural-extension services. However, existing studies indicate that the intensity of pesticide use has failed to decline in spite of reinforced government supervision and technology extension [3]. In order to accelerate the green development of agriculture, it is crucial to gain a deeper understanding of the current situation of pesticide use by farmers and its underlying factors.

Previous studies have thoroughly discussed the determinants of pesticide use by farmers. While most previous studies focus on individual and household characteristics, farmers' lack of technical knowledge contributes largely to the overuse of pesticides in China [4]. Several studies also point out that farmers' decisions regarding pesticide use frequently rely on their subjective estimates of pesticide marginal productivity, and their estimates of losses caused by pest infestation are often considerably larger than the actual levels [5]. Under the circumstance of having rich technical knowledge, if farmers have more accurate estimates of pest outbreaks, this will reduce their pesticide use [6,7]. We note that the quality of information acquisition might be a decisive factor in farmers' level of technical knowledge [1]. It has been found that government agricultural-extension agents and pesticide retailers might be the main sources of technical information for farmers. However, due to the asymmetry and uncertainty of information, previous studies regarding the impact of multi-source information acquisition on farmers' pesticide use has not reached a consistent conclusion [8,9].

Given the new round of the technological revolution, Internet-based information services have gradually become farmers' source of information acquisition regarding agricultural production [10]. In recent years, the Chinese government has made huge efforts to improve the Internet infrastructure in rural areas, with the rural Internet penetration rate rising from 38.4% in 2018 to 66.5% in 2023, and the number of rural Internet users exceeds 326 million. In this context, a growing number of Chinese farmers use smartphones and computers to surf the Internet for fun or to acquire technical information regarding agricultural production. For example, they can obtain technical knowledge information using WeChat, Tencent QQ, and other applications (Apps). In fact, the Internet is an effective tool for sharing knowledge and information across spatial and temporal boundaries, reducing the information asymmetry between information providers and farmers [11]. It is clear from several studies that the use of smartphones and computers has a significantly positive impact on farmers' entrepreneurship, income, and consumption [12–14]. It can also help farmers to achieve precise production, purchasing, and marketing outcomes, thus improving agricultural productivity [15–17].

Although previous studies have discussed the importance of Internet use and its impact on agricultural production, whether and how Internet-based information acquisition affects pesticide use by farmers deserves further research. The Internet can make it easier for farmers to access timely, effective, and region-specific technical information using smartphones and computers, avoiding the problems concerning information asymmetry and the poor timeliness of governmental agricultural-extension services and pesticide-retailer information provision [10,13]. In the context of weakening of the role of the grassroots governmental agricultural-extension service system in China [8], exploring the impact of the Internet-based acquisition of technical information on pesticide use and its impact mechanism may have theoretical and policy implications for the innovation of agricultural-extension models and the promotion of pesticide reduction.

To fill this research gap, this study analyzes the impact and mechanism of Internet-based information acquisition on pesticide use, using survey data covering 1113 rice farmers in Guizhou, Hubei, Jiangsu, and Zhejiang provinces in the Yangtze River Basin in China. Overall, the novelty and marginal contribution of this study to the existing literature is twofold. First, while the relationship between Internet use and pesticide use has been previously analyzed, there lacks an empirical analysis of the impact mechanism [18,19]. This study uses farmers' level of technical knowledge as a mediating variable and examines if Internet-based information acquisition affects farmers' pesticide use by influencing their technical knowledge. Second, Internet use has often been defined as farmers using smartphones and computers to surf the Internet [20–23]. This is not a desirable variable to describe farmers' Internet-based information acquisition, because farmers would surf the Internet just for fun rather than obtaining technical information regarding agricultural production. In comparison, this study provides a precise definition of Internet-based information acquisition: a farmer acquiring technical information regarding agricultural production through Internet platforms (e.g., WeChat or Apps).

The remainder of this study proceed as follows: Section 2 provides a theoretical analysis of how Internet-based information acquisition affects farmers' pesticide use, as well as the hypotheses to be examined. Section 3 introduces the study area, data collection, variable definitions, and the econometric model. In Section 4, the results of the empirical analysis are presented with the discussion. The final section concludes the study with policy implications.

2. Theoretical Analysis and Hypothesis

Theoretically, the lack of technical information for farmers increases their perceived uncertainty, which leads to a high dependence on pesticide use [1]. From the perspective of technical information provision, the main sources of technical information on pesticide use available to farmers include government agricultural-extension agents and pesticide retailers. China has the largest government agricultural-extension system in the world, but its commercialization reform in the late 1980s, which allowed agricultural-extension agents to sell pesticides, has been considered to increase pesticide use by farmers [24]. While government agricultural-extension agents have been prohibited from selling pesticides since 2006, the problem of pesticide overuse that emerged in the late 1990s has not fundamentally changed [25]. Moreover, pesticide retailers have also become an important source of technical information for farmers. However, they have been found to recommend excessive pesticide use to farmers due to their pursuit of business profits [1]. In particular, they have also been found to recommend incorrect pesticides to farmers in the context of limited expertise and lack of supervision [26].

In addition to examining the influence of technical information on pesticide use from the supply side, it is also important to identify the underlying causes of pesticide overuse from the demand side of technical information. On the one hand, a survey among 330 farmers revealed that nearly 80% of farmers had demand for technical information related to pesticide use [27]. However, the highly bureaucratic governmental agricultural-extension system is unable to respond promptly to farmers' demand for technical information related to agricultural production [28]. Moreover, its one-size-fits-all technology extension project and model do not match the characteristics of farmers' production and pest management [19]. In the absence of fully meeting diverse technical demands, farmers' dependence on pesticide use has become larger [1]. On the other hand, the agricultural-extension services provided by the socialized service departments are mainly based on the demonstration-driven model. However, the demonstration farm households need to acquire additional social and financial resources. Thus, this improves access to agricultural-extension services for new agricultural business entities and makes it difficult for smallholder farmers to access good-quality agricultural-extension services [29]. We note that rural China is dominated by smallholder farmers facing high costs related to information acquisition and searches [30]. A survey of 2293 farmers found that over 80% of farmers make decisions on pesticide use mainly based on their individual experience due to their low levels of education and limited pesticide knowledge [28], which in turn results in higher levels of pesticide use [1].

It should be noted that as information technology develops rapidly, Internet-plus agricultural-extension services provide farmers with relatively accurate technical information on pesticide use [11]. We note that the impact of digitalized agricultural technical information on pesticide use is roughly equal to, or even better than, that of government agricultural-extension services [16,19]. On the one hand, the Internet-based acquisition of agricultural technical information improves the accessibility of information. Internet-based agricultural technical information is characterized by rapid dissemination, storage, and replication. It can solve the problem of information asymmetry between the supply and demand sides of agricultural-extension services and facilitate farmers' search for technical information related to pest control and pesticide use [19]. On the other hand, the Internet-based acquisition of agricultural technical information improves the timeliness of pest prediction and forecasting. Due to the time-sensitive nature of pest control, farmers may not take optimal control measures if they do not receive timely pest-forecasting information. This can result in the overuse of pesticides in attempts to reduce the loss of yields caused by pest outbreaks [6]. The timeliness of Internet-based agricultural technical information enables farmers to receive timely and accurate information on the timing of pest control prior to pest outbreaks. This reduces the probability of pesticide overuse in the later stages of pest control. In this context, the first hypothesis is proposed as follows:

Hypothesis 1. *Internet-based information acquisition would exert a negative impact on pesticide-use intensity among farmers*.

From a mechanism perspective, Internet-based information acquisition can improve farmers' knowledge of agrochemical use, thereby reducing the intensity of pesticide use in agricultural production. Several studies found that it provides an open platform for farmers to communicate with agronomists or experts, and it breaks down the spatial and temporal barriers of knowledge and information transfer [16], which enables farmers to gain knowledge related to agricultural production and technology online, thus continuously accumulating human capital [29]. In addition, previous studies pointed out that the increase in farmers' knowledge level has a significantly negative impact on the intensity of pesticide use, and for each unit increase in farmers' knowledge level, their pesticide use would be reduced by 1.95 kg/ha [30]. From this perspective, Internet-based information acquisition can contribute to a reduction in pesticide use and the development of green agriculture by improving farmers' knowledge level. Thus, the second hypothesis is developed as follows:

Hypothesis 2. *Internet-based information acquisition would reduce pesticide-use intensity through improving farmers' technical knowledge level*.

There may exist heterogeneous impacts of Internet-based information acquisition on pesticide use across different levels of education or farm sizes. On the one hand, farmers with lower levels of education face higher technological thresholds in accessing Internet-based agricultural technical information. Even if they use modern information and communication tools, they may do so to access other non-agricultural production-related information, such as entertainment [23,31]. Therefore, Internet-based information acquisition may have a smaller impact on pesticide use among farmers with lower education levels. In terms of farm size, on the other hand, the probability of obtaining technical information is lower for smallholder farmers. When smallholder farmers obtain technical information from Internet platforms, their technical knowledge can also be significantly improved, which may lead to a reduction in pesticide use [19]. In comparison, large-scale farmers may choose to reduce yield losses by increasing pesticide use for risk-aversion reasons [32]. In particular, there may exist a lack of incentive for large-scale farmers to reduce pesticide use in the context of information asymmetry in the production and consumption of agricultural products [33].

Hypothesis 3a. *The impact of Internet-based information acquisition on pesticide use by farmers varies across education levels*.

Hypothesis 3b. *The impact of Internet-based information acquisition on pesticide use varies across farm sizes*.

3. Methods and Materials

3.1. Study Area and Data Collection

The data used in this study were collected from a survey of 1133 rice farmers in the Yangtze River Basin in China between October and November in 2016. We note that rice is the most important food crop in China, and the problem of pesticide overuse in rice cultivation is severe and repeatedly documented in the literature [34–36]. Hence, our analysis with a focus on rice farmers may have important policy implications for reducing pesticide use in rice production in China. Moreover, the Yangtze River Basin is the largest rice-producing region in China, producing over 60% of the total rice output in China [37]. Data were obtained in four provinces in the Yangtze River Basin, including the Guizhou, Hubei, Jiangsu, and Zhejiang provinces. Guizhou is in the upper reach of the Yangtze River Basin, Hubei is in the middle reach of the Yangtze River Basin, and Jiangsu and Zhejiang are in the lower reach of the Yangtze River Basin. All four provinces are the main rice-producing provinces in the Yangtze River Basin. In this context, our sample has good representativeness.

The farmer survey was conducted using a random sampling methodology, with specific sampling steps employed. First, the rice-producing counties (districts and cities) in each province were divided into high and low groups based on their per capita income level. Two counties (districts and cities) were randomly selected from each group. Second, two townships were randomly selected in each county (district and city) following a similar methodology. Third, two villages were randomly selected in each township. Fourth, 15–20 rice farmers were randomly selected in each village using the random sampling method. To ensure the reliability of the survey data, the group surveyed only the agricultural decision-maker of each farm household. The survey collected a considerable amount of information, such as the individual and household characteristics of farmers (e.g., gender, age, education), the situation of Internet-based information acquisition, and other inputs and outputs in rice production. After excluding a small number of sampled farmers who could not provide information on pesticide use, a total of 1113 farmers remained in the sample.

3.2. Variable Definition

(1) Dependent variable. In this study, the intensity of pesticide use is defined as the dependent variable. It represents the application rate of total pesticides used per unit of rice-sown area. Pesticides used by farmers include insecticides, fungicides, and herbicides.

(2) Independent variable. A dummy variable describing farmers' acquisition of Internet-based information is defined as the core independent variable. In this study, the dummy variable of Internet-based information acquisition is equal to one when a farmer obtains technical information from the Internet or shares technical information through Internet platforms, and it is zero otherwise.

(3) Control variables. This study considers several variables that may also affect the intensity of pesticide use. The control variables in this study consist of four groups. The first group included farmers' individual and household characteristics, such as gender, age, education, distance from the household to the county, and the number of laborers in the household. The second group included economic and technical training factors, such as the price of pesticides and whether the farmer participated in technical training. The third group contained the characteristics of rice cultivation, including the topography of the rice cultivation plot, the rice-sown area, the season of rice cultivation, the adoption of direct seeding, and the adoption of hybrid varieties. The fourth group of control variables included a provincial dummy variable, which serves to control for the impact of region-specific unobservable factors (e.g., pesticide policies and weather conditions).

(4) Mediating variable. Farmers' technical knowledge about agrochemical use is employed as a mediating variable that connects farmers' Internet-based information acquisition and pesticide-use intensity. Each sampled farmer was asked to participate in a pesticide-related knowledge test containing ten questions. If a farmer answered a question correctly, she/he received a point. Thus, the score of farmers' technical knowledge ranges from zero to ten.

(5) Instrumental variable. There are two instrumental variables. It should be noted that constructing instrumental variables based on peer effects is common in the previous literature, with good results [19,38,39]. First, this study identifies whether there are other farmers in the same village obtaining technical information from the Internet, and then uses

this as an instrumental variable for farmers' Internet-based information acquisition. In the context, a dummy variable is equal to one if a farmer obtained technical information from the Internet, and it is zero otherwise. Under the conditions of rural acquaintance society, the behavior of farmers is significantly influenced by the behavior of other farmers in the same village [16]. If other farmers in the same village obtained technical information from the Internet, the farmer was more likely to do so. Thus, this dummy variable theoretically satisfies the correlation condition for instrumental variables. In addition, the decision of other farmers in the same village to obtain technical information via the Internet would not directly influence the intensity of pesticide use by the farmer except through her/his Internet-based information acquisition. This implies that the dummy variable also theoretically meets the exclusive constraint for instrumental variables. Second, this study employs the average score of farmers' technical knowledge among other farmers in the same village as an instrumental variable for the technical knowledge of the farmer.

The definitions and descriptive statistics of main variables are presented in Table 1.

Table 1. Definitions and descriptive statistics of main variables.

Variable	Definition	Mean (SD)
Pesticide use	The intensity of pesticide use (kg/ha)	4.53 (7.31)
Internet use	One if a farmer obtains technical information from the Internet, zero otherwise	0.14 (0.34)
Male	One if a farmer is male, zero otherwise	0.90 (0.29)
Age	Age of a farmer (years)	57.06 (9.66)
Education	Years of education (years)	6.62 (3.28)
Training	One if a farmer participates technical training, zero otherwise	0.24 (0.43)
Pesticide price	Price of pesticide (yuan/kg)	134.92 (128.14)
Flat land	One if land is flat, zero otherwise	0.69 (0.46)
Distance	Distance to the county (km)	20.54 (11.35)
Labor	Number of household laborers	3.00 (1.25)
Sown area	Total sown area of rice (ha)	1.96 (11.00)
Late-season rice	One if a farmer grows late-season rice, zero otherwise	0.48 (0.50)
Direct seeding	One if a farmer adopts direct seeding, zero otherwise	0.47 (0.50)
Hybrid varieties	One if a farmer adopts hybrid varieties, zero otherwise	0.48 (0.50)
Knowledge	Score of a farmer's technical knowledge	5.24 (1.89)
IV1	One if another farmer in the same village obtains information from the Internet, zero otherwise	0.81 (0.40)
IV2	The average knowledge score among other farmers in the same village	5.24 (0.02)
Observations		1113

Notes: Data from the authors' survey. Figures in parentheses are standard deviations.

Table 2 presents the mean differences between the obtainers and non-obtainers of Internet-based information. It is notable that there are significant differences in most of the variables between these two groups of rice farmers, which may indicate the presence of self-selection in rice farmers' acquisition of Internet-based information.

3.3. Treatment-Effects Model

The present study aims to examine the impact of Internet-based information acquisition on farmers' pesticide-use intensity. We note that there may be other factors that would influence the intensity of pesticide use by farmers. Accordingly, this study employs the treatment-effects model proposed by Maddala to address the self-selection problem [40], and an equation with pesticide-use intensity as the dependent variable is developed as follows:

$$Y_i = \alpha + \beta M_i + \boldsymbol{X}_i^{\prime}\gamma + u_i \quad (1)$$

where i indicates the i-th farmer; Y_i is the intensity of pesticide use by farmers in rice production; M_i is a dummy variable that is equal to one if a farmer obtains Internet-based information, and it is zero otherwise; $\boldsymbol{X}_i$ is a set of control variables affecting the intensity of pesticide use by farmers; α, β and γ are coefficients to be estimated; and u_i indicates the random error.

Table 2. Mean differences between the Internet users and non-users.

Variable	Internet Users	Internet Non-Users	Mean Differences
Pesticide use	4.74 (7.74)	3.15 (3.18)	1.59 **
Male	0.91 (0.29)	0.90 (0.30)	0.00
Age	58.22 (9.21)	49.66 (9.23)	8.56 ***
Education	6.24 (3.22)	9.04 (2.63)	−2.79 ***
Training	0.19 (0.39)	0.57 (0.50)	−0.38 ***
Pesticide price	129.93 (123.51)	166.72 (151.01)	−36.79 ***
Flat land	0.67 (0.47)	0.81 (0.39)	−0.14 ***
Distance	20.56 (11.53)	20.47 (10.20)	0.08
Labor	3.01 (1.26)	2.91 (1.18)	0.10
Sown area	1.02 (3.81)	7.95 (27.60)	−6.93 ***
Late-season rice	0.47 (0.50)	0.51 (0.50)	−0.04
Direct seeding	0.48 (0.50)	0.42 (0.49)	0.06
Hybrid varieties	0.49 (0.50)	0.42 (0.50)	0.07
Knowledge	5.07 (1.85)	6.35 (1.79)	−1.28 ***
IV1	0.78 (0.41)	0.95 (0.21)	−0.17 ***
IV2	5.20 (0.76)	5.55 (0.77)	−0.35 ***
Observations	962	151	

Notes: Data from the authors' survey. Figures in parentheses are standard deviations. ***, and ** indicate significance at the 1%, and 5% level, respectively.

If M_i is exogenous, the ordinary least-squares (OLS) method can be used to estimate Equation (1) and examine the impact of Internet-based information acquisition on farmers' pesticide-use intensity. Whether a farmer obtains technical information from the Internet can be described as a latent variable (M_i^*), which is determined by both observable and unobservable factors. In this study, the farmer's Internet-based information acquisition is not the result of random selection by farmers [13]. Thus, the latent variable can be expressed as follows:

$$M_i^* = \vartheta + \boldsymbol{Z_i'}\delta + v_i \qquad M_i = \begin{cases} 1, \ \boldsymbol{M_i^*} > 0 \\ 0, \ \boldsymbol{M_i^*} \leq 0 \end{cases} \tag{2}$$

where $\boldsymbol{Z}_i$ includes the factors influencing farmers' Internet-based information acquisition, and there is at least one variable included in $\boldsymbol{Z}_i$ but not included in $\boldsymbol{X}_i$. Obviously, this variable is the instrumental variable. ϑ andδ are coefficients to be estimated, and v_i indicates the random error.

In addition, the random error terms u_i and v_i in Equations (1) and (2) should obey a binary normal distribution with the following covariance matrix:

$$Cov(u_i, v_i) = \begin{bmatrix} \sigma_u^2 & \rho\sigma_u \\ \rho\sigma_u & 1 \end{bmatrix} \tag{3}$$

where the variance ${\sigma_v}^2$ of v_i is normalized to 1, and ρ is the correlation coefficient between the random error term u_i and v_i. It should be noted that a farmer's Internet-based information acquisition is endogenous due to self-selection bias when the correlation coefficient ρ is not equal to zero, and it is exogenous when ρ is equal to zero.

Given the self-selection issue of Internet-based information acquisition, the conditional expectations of pesticide-use intensity for obtainers and non-obtainers of Internet-based information can be expressed as follows:

$$E(Y_i|M_i = 1) = \alpha + \beta + \boldsymbol{X_i'}\gamma + E(u_i|M_i = 1) \tag{4}$$

$$E(Y_i|M_i = 0) = \alpha + \boldsymbol{X_i'}\gamma + E(u_i|M_i = 0) \tag{5}$$

Combining Equations (4) and (5), the average treatment effect (ATT) of Internet-based information acquisition on pesticide-use intensity can be obtained as follows:

$$\begin{aligned} ATT &= E(Y_i|M_i = 1) - E(Y_i|M_i = 0) \\ &= \beta + \rho\sigma_u\lambda\left(-\vartheta - \mathbf{Z}_i'\delta\right) + \rho\sigma_u\lambda\left(\vartheta + \mathbf{Z}_i'\delta\right) \\ &= \beta + \rho\sigma_u\left[\lambda\left(-\vartheta - \mathbf{Z}_i'\delta\right) + \lambda\left(\vartheta + \mathbf{Z}_i'\delta\right)\right] \end{aligned} \quad (6)$$

where $\lambda(\cdot)$ indicates the inverse Mills function. We note that the ATT is calculated after addressing the self-selection bias caused by observable and unobservable factors [29]. With the help of the ATT, it is possible to examine the impact of Internet-based information acquisition on the intensity of pesticide use.

4. Results and Discussion

4.1. Effects of Internet-Based Information Acquisition on Pesticide Use

This study examined the estimated impact of Internet-based information acquisition and other factors on pesticide-use intensity using the treatment-effects model (Table 3). The estimation results using both the OLS method and treatment-effects model are presented for comparison. This study addresses the issue of self-selection and tests the validity of the instrumental variables. First, the correlation coefficient ρ is positive and significant at the 5% level, thereby rejecting the null hypothesis that u_i and v_i are uncorrelated. This suggests a positive self-selection bias. Moreover, the χ^2 statistic of the independent equation Wald test is significantly equal to 5.780 at the 5% level, indicating that the treatment and outcome equations are dependent. This further implies that Internet-based information acquisition is endogenous due to the self-selection issue. Secondly, this study uses a two-stage least-squares method to test whether the instrumental variable is weak. The results indicate that the first-stage F-statistic is significantly equal to 11.46 at the 1% level, which is considerably larger than its critical value of 10. This demonstrates that the presence of other farmers in the same village who obtained technical information from the Internet is not a weak instrumental variable. In addition, this study employs an OLS method. Specifically, the intensity of pesticide use is regressed on the instrumental variable, Internet-based information acquisition and other control variables. The estimated coefficient of the instrumental variable was found to be equal to -1.284 but not statistically significant, indicating that the instrumental variable satisfies the exclusive constraint. Thus, the utilization of a treatment-effects model is reasonable, and the instrumental variable is valid.

In addition to the instrumental variable, the results showed that farmers' Internet-based information acquisition is significantly affected by farmers' age and education, the rice-sown area, and the adoption of hybrid varieties (Table 3). In this case, the estimated coefficient of farmer's age is equal to -0.037, which is statistically significant at the 1% level. This suggests that as farmers become older, their probability of obtaining technical information from the Internet decreases. Farmers' education level is significantly positively correlated with Internet-based information acquisition. It has been demonstrated that most farmers that obtain technical information from the Internet are young adults with higher education. Therefore, it is reasonable that the obtainers of Internet-based information are typically younger [10,23]. Moreover, an increase in the level of education can significantly increase the use of the Internet [41]. Furthermore, the probability of Internet-based information acquisition is higher for rice farmers with a larger farm size. As previously pointed out, the farmers with a larger farm size would also have stronger willingness to acquire new technologies, and thus, they would be more likely to obtain technical information from the Internet [42]. In addition, farmers' participation in technical training or adoption of hybrid varieties also had a significant impact on Internet-based information acquisition, which is also consistent with the findings of previous studies [43,44].

Table 3. Impact of the Internet-based information acquisition on pesticide use.

Variable	OLS Method	Treatment-Effects Model	
		Internet Use	Pesticide Use
Internet use	−0.857 ** (0.358)		−2.036 *** (0.690)
Male	0.165 (0.578)	−0.195 (0.200)	0.129 (0.571)
Age	0.002 (0.022)	−0.037 *** (0.007)	−0.006 (0.023)
Education	−0.032 (0.073)	0.123 *** (0.022)	−0.012 (0.071)
Training	−0.860 ** (0.386)	0.690 *** (0.116)	−0.671 * (0.388)
Pesticide price	−0.012 *** (0.001)	0.001 (0.000)	−0.012 *** (0.001)
Flat land	−0.334 (0.441)	0.143 (0.178)	−0.302 (0.446)
Distance	−0.016 (0.013)	−0.003 (0.005)	−0.017 (0.013)
Labor	−0.085 (0.178)	0.027 (0.049)	−0.082 (0.177)
Sown area	0.013 ** (0.006)	0.023 *** (0.008)	0.018 ** (0.008)
Late-season rice	0.484 (0.350)	0.122 (0.164)	0.510 (0.347)
Direct seeding	−0.134 (0.578)	−0.143 (0.139)	−0.151 (0.571)
Hybrid varieties	0.628 (0.618)	−0.342 ** (0.173)	0.577 (0.602)
IV1		0.671 *** (0.229)	
Constant	8.316 *** (1.431)	−0.944 * (0.512)	8.769 *** (1.463)
Provincial effects	Yes	Yes	Yes
Correlation coefficient (ρ)		0.100 **	
Indep. eqs. (Wald test χ^2)		5.780 **	
Weak instrument test (F statistic)		11.460 ***	
Exogenous test		−1.284 (0.798)	
Observations		1113	

Notes: Figures in parentheses are robust standard errors. ***, **, and * indicate the significance at the 1%, 5%, and 10% level, respectively.

The results of the outcome equation indicate that Internet-based information acquisition led to a significant reduction in pesticide-use intensity in rice production (Table 3). The estimated coefficient of Internet-based information acquisition is equal to −2.036 and significant at the 1% level, which means that it contributed to the reduction in pesticide-use intensity by 2.036 kg/ha, with other factors held constant. This finding is consistent with previous studies focusing on the impact of smartphone use on agricultural chemical use [40,42]. It should be noted that the estimation results using the OLS method show that the estimated coefficient of Internet-based information acquisition is smaller than that using the treatment-effects model. This suggests that the OLS method may lead to an underestimation of the impact of Internet-based information acquisition on pesticide use due to the self-selection issue.

In addition, the price of pesticides, technical training, and the rice-sown area also exhibited a significant impact on pesticide use (Table 3). Specifically, the estimated coefficient of pesticide prices is equal to −0.012 and significant at the 1% level, indicating that pesticide use by farmers is economically rational [25]. The estimated coefficient of participation in technical training is equal to −0.671 and significant at the 10% level, indicating that technical training can significantly reduce farmers' pesticide use. Similar findings were also found in previous studies [45]. The estimated coefficient of the rice-sown area is equal to 0.018 and significant at the 5% level, consistent with a previous study that revealed that farmers who engaged in large-scale planting operations were more likely to overuse pesticides as a means of risk mitigation [46].

4.2. Robustness Checks

To check the robustness of the above findings, this study employs an endogenous switching regression model for further analysis. This can also be used to correct for the self-selection bias arising from both observable and unobservable factors. The core idea of endogenous switching regression modeling is to examine the treatment effect under counterfactual scenarios [10]. Therefore, we can construct a counterfactual analytical framework based on the regression results to estimate the treatment effect of Internet-based information acquisition on pesticide use by comparing the expected value of pesticide use between farmers obtaining technical information from the Internet and those not obtaining technical information from the Internet. In this context, we can obtain the average treatment effect for the obtainers of Internet-based information (ATT) and non-obtainers of Internet-based information (ATU). Table 4 reports the estimation results of ATT and ATU.

Table 4. Average treatment effects of the Internet-based information acquisition on pesticide use.

Group	Use the Internet	Not Use the Internet	ATT	ATU
Internet users	3.154 (0.139)	5.142 (0.212)	−1.988 *** (0.253)	
Internet non-users	3.788 (0.051)	4.741 (0.066)		−0.953 *** (0.083)

Notes: Figures in parentheses are standard deviations. *** indicates the significance at the 1% level.

Table 4 shows that both the ATT and ATU are significantly negative at the 1% level. In the context of the counterfactual scenario, the intensity of pesticide use among the obtainers of Internet-based information would increase by 1.988 kg/ha, which is equal to an increase of 63.03% when they did not obtain technical information from the Internet. In addition, the intensity of pesticide use among the non-obtainers of Internet-based information would decrease by 0.953 kg/ha, which is equal to a reduction of 25.16% when they obtained technical information from the Internet. These findings reconfirm that Internet-based information acquisition can significantly reduce the intensity of pesticide use among rice farmers, which provides evidence for the robustness of the estimation results in Table 3. In fact, our findings on the negative impact of Internet-based information acquisition on pesticide use are consistent with another study that illustrates a negative impact of Internet use on farmers' use of pesticides [47].

4.3. Mechanism Analysis

Based on the mediation analysis proposed by Baron and Kenny [48], this study further examines whether Internet-based information acquisition would reduce pesticide use by improving farmers' technical knowledge. The mechanism analysis is conducted in three steps. First, the impact of Internet-based information acquisition and pesticide use is re-estimated, accounting for other control variables. Second, a model is estimated to examine the impact of farmers' Internet-based information acquisition on their technical knowledge. Third, this study estimates the impact of both farmers' Internet-based information acquisition and technical knowledge on pesticide use. Given the potential endogeneity of farmers' technical knowledge, a two-stage least-squares approach is employed in the third step. The results of mechanism analysis are presented in Table 5, which indicate that Internet-based information acquisition would reduce pesticide use by improving farmers' technical knowledge. We note that the positive contribution of Internet use to the improvement of farmers' knowledge and human capital accumulation has also been confirmed in previous studies [49]. However, the estimated coefficient of Internet-based information acquisition became no longer significant when farmers' technical knowledge was included in the model, whereas the estimated coefficient of farmers' technical knowledge was −1.648 and significant at the 5% level. This strongly suggests that farmers' technical knowledge plays a fully mediating role in the relationship between the Internet-based information acquisition and pesticide use.

4.4. Heterogeneity Analysis

The theoretical analysis of this study suggests that the impact of Internet-based information acquisition on rice farmers' pesticide use may be heterogeneous, varying with farmers' education level and the rice-sown area. To examine the heterogeneous impacts, the study re-estimates the treatment-effects models for subgroups by farmers' education level and the rice-sown area. First, all the sampled farmers were divided into two groups based on their education level, with one group of farmers having no more than six years of schooling education and the other group of farmers having more than six years of schooling education. Second, all the farmers were divided into two groups based on their rice-sown area, with one group of farmers whose rice-sown area was not larger than 0.5 ha and the other group of farmers whose rice-sown area was larger than 0.5 ha. Table 6 shows the estimated results of the heterogeneity analysis using the treatment-effects model.

Table 5. Regression results for the mechanism analysis.

Variable	OLS (Pesticide Use)	OLS (Knowledge)	2SLS (Pesticide Use)
Internet use	−0.857 ** (0.358)	0.601 *** (0.161)	0.134 (0.581)
Knowledge			−1.648 ** (0.737)
Control variables	Yes	Yes	Yes
Hausman test			3.81 *
F statistic			21.63 ***
Observations		1113	

Notes: Figures in parentheses are robust standard errors. ***, **, and * indicate the significance at the 1%, 5%, and 10% level, respectively.

Table 6. Estimation results of heterogeneity analysis using the treatment-effects model.

Variable	Education Level		Rice-Sown Area	
	≤Six Years	>Six Years	≤0.5 ha	>0.5 ha
Internet use	−2.849 ** (1.331)	−3.211 *** (0.812)	−2.916 *** (0.702)	−2.434 (2.084)
Control variables	Yes	Yes	Yes	Yes
Correlation coefficient (ρ)	0.162 **	0.151 ***	0.082 ***	0.272 **
Indep. eqs. (Wald test χ^2)	5.670 **	22.020 ***	8.630 ***	4.500 **
Observations	530	583	801	312

Notes: Figures in parentheses are robust standard errors. ***, and ** indicate the significance at the 1%, and 5% level, respectively.

The results in Table 6 show that there are heterogeneous impacts of Internet-based information acquisition on pesticide use across different levels of farmers' education and rice-sown areas. While the coefficients of Internet-based information acquisition are significantly negative in the models for farmers with different levels of education, the magnitude of the coefficients differs across groups. Specifically, the estimated coefficient of Internet-based information acquisition is equal to −2.849 for farmers with no more than six years of schooling education, and it is −3.211 for those with more than six years of schooling education. This means that the pesticide-reduction impact is greater for farmers with higher levels of education. Meanwhile, the impact of Internet-based information acquisition is also heterogeneous among groups with different rice-sown areas. Specifically, Internet-based information acquisition was found to significantly reduce the intensity of pesticide use by 2.916 kg/ha among farmers whose rice-sown area was not larger than 0.5 ha. However, it did not have a significantly negative impact on pesticide-use intensity for farmers with a rice-sown area of more than 0.5 ha.

5. Conclusions and Policy Implications

Using survey data from a total sample of 1113 rice farmers in Guizhou, Hubei, Jiangsu, and Zhejiang provinces in the Yangtze River Basin in China, this study explores the impact of Internet-based information acquisition on pesticide use in rice production in depth. The treatment-effects model is employed to address the self-selection issue. The findings demonstrate that Internet-based information acquisition significantly reduces the intensity of pesticide use in rice production by 2.036 kg/ha. The robustness checks reveal that if the obtainers of Internet-based information did not obtain technical information from the Internet, their pesticide-use intensity would increase by 1.988 kg/ha, and if the non-obtainers of Internet-based information obtained information from the Internet, their pesticide-use intensity would decrease by 0.953 kg/ha. Moreover, farmers' technical knowledge plays a crucial mediating role in connecting farmers' Internet-based information acquisition and their pesticide use. In addition, the impacts of Internet-based information acquisition on pesticide-use intensity are heterogeneous in terms of rice farmers' education level and their rice-sown area.

The findings of this study have several important policy implications. Firstly, efforts should be made to accelerate the construction of rural information infrastructure networks and expand the channels through which smallholder farmers can obtain technical information from Internet platforms. Despite the potential of Internet-based information acquisition to reduce information asymmetry, less than one-fifth of farmers in China obtain technical information from the Internet. Therefore, the government should implement relevant policies and enhance resource support accordingly, and it also needs to improve the Broadband China Action Plan. It is recommended to promote the construction of network infrastructure, including 5G, gigabit fiber, and satellite 4G, in eligible rural areas. To encourage farmers to use the Internet, it is necessary to develop data packages tailored to their specific characteristics and needs. It is also imperative to accelerate the dissemination of Internet technologies to farmers, so that a larger proportion of farmers can benefit from improved services. Secondly, the government should promote the 'Internet plus' agricultural-extension services and standardize Internet-based agricultural technical information. In the context of the variety of information on the Internet, the government should support agricultural technical information on the Internet and the development of agricultural technical information-dissemination platforms, which can be designated as official and authoritative information sources. Moreover, the government can make efforts to provide a comprehensive range of agricultural technical resources, including technology tutorials, case sharing, expert consultation, and other relevant materials, to meet the diverse needs of farmers. In addition, a regulatory and examination mechanism for agricultural technical information should also be established to clarify the responsibilities and obligations of information providers as well as authorize the auditing of key information. In this context, farmers can receive more accurate agricultural technical information. Thirdly, it is imperative to improve farmers' skills in using the Internet, with a special focus on those with limited education. The content of the training program should be based on a realistic understanding of agricultural production and be closely related to the actual needs of farmers. The content on live streaming and inclusive finance would be mainly targeted at returning migrant workers, new business entities and other types of farmers. Efforts should be made to provide skill training on smartphone and computer usage for the elderly population in rural areas, which can facilitate the improvement of participants' skills in using the Internet and their ability to identify the quality of information on the Internet. This approach would help farmers to effectively obtain Internet-based information, thereby reducing the use of pesticides by farmer.

It should be noted that this study has some limitations, and there is potential for future research. First, this study provides insights into the impact of Internet-based information acquisition on pesticide use in rice production, but its impact in the production of other crops remains unknown. Second, the data were collected in October and November in 2016, and thus, to some extent, were outdated, but this would not interfere with the discussion of the impact of Internet-based information acquisition on pesticide use and the mediating role of farmers' technical knowledge. Furthermore, we would perform additional surveys in the future as conditions permit. Third, digital agriculture is increasingly showing its great potential to contribute to the green transformation of agriculture. In the future, theoretical and empirical analyses should be conducted on the impacts of the application of Internet-based digital technologies, such as big data and artificial intelligence, to provide a scientific basis for accelerating the green transformation of agriculture.

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References

1. Sun, S.; Hu, R.; Zhang, C. Effects of technological information sources on rice farmers' pesticide overuse and underuse behavior. *World Agric.* **2021**, *8*, 97–109. (In Chinese)
2. Gao, J.; Shi, Q. The shift of agricultural production growth path in China: Based on the micro perspective of farm input. *Manag. World* **2021**, *37*, 124–134. (In Chinese)
3. Pan, D.; Yang, Y.; Zhong, H.; Guo, Q. Spatial-temporal difference of pesticide over-application about main grain crops in China. *Rev. Econ. Res.* **2018**, *33*, 16–23. (In Chinese)
4. Pan, Y.; Ren, Y.; Luning P, A. Factors influencing Chinese farmers' proper pesticide application in agricultural products-A review. *Food Control* **2021**, *122*, 107788. [CrossRef]
5. Zhu, D.; Kong, X.; Gu, J. Irrational balance of farmers' pesticide overuse: Evidence from farmers in southern Jiangsu, China. *Chin. Rural Econ.* **2014**, *8*, 17–29. (In Chinese)
6. Sun, S.; Li, Z.; Zhang, C.; Hu, R. Effects of technological information sources on farmers' pest control behaviors. *Res. Agric. Modern.* **2021**, *42*, 900–908. (In Chinese)
7. Chen, R.; Huang, J.; Qiao, F. Farmers' knowledge on pest management and pesticide use in Bt cotton production in China. *China Econ. Rev.* **2013**, *27*, 15–24. [CrossRef]
8. Pan, D.; Zhang, N.; Kong, F. Does it matter who gives information? The impact of information sources on farmers' pesticide use in China. *J. Asian Econ.* **2021**, *76*, 101345. [CrossRef]
9. Li, Z.; Zhang, C.; Sun, S. Pesticide sales and application behavior of pesticide shopkeepers under dual identities. *China Soft Sci.* **2023**, *2*, 95–103. (In Chinese)
10. Su, L.; Kong, R. Does internet use improve rural households' entrepreneurial performance? An empirical analysis based on endogenous switching regression model. *Chin. Rural Econ.* **2020**, *2*, 62–80. (In Chinese)
11. Gao, Y.; Zhao, D.; Yu, L.; Yang, H. Influence of a new agricultural technology extension mode on farmers' technology adoption behavior in China. *J. Rural Stud.* **2020**, *76*, 173–183. [CrossRef]
12. Zhang, Y.; Xu, L. The impact of internet use on family life consumption of farmers in western poverty-stricken areas: An analysis based on household survey of 1735 farmers in Gansu province. *Chin. Rural Econ.* **2019**, *2*, 42–59. (In Chinese)
13. Qiu, Z.; Zhou, Y. The mechanism of the role of e-commerce in increasing rural household income: An analysis based on a micro empirical test of the interaction between demand and supply. *Chin. Rural Econ.* **2021**, *4*, 36–52. (In Chinese)
14. Zeng, M.; Du, J.; Zhu, X.; Deng, X. Does internet use drive rural household savings? Evidence from 7825 farmer households in rural China. *Finance Res. Lett.* **2023**, *57*, 104275. [CrossRef]
15. Zheng, H.; Ma, W. Economic benefits of internet use for smallholder wheat farmers. *Appl. Econ.* **2023**, *56*, 398–413. [CrossRef]
16. Zhu, X.; Hu, R.; Zhang, C.; Shi, G. Does internet use improve technical efficiency? Evidence from apple production in China. *Technol. Forecast. Soc. Chang.* **2021**, *166*, 120662. [CrossRef]
17. Ogutu, S.; Okello, J.; Otieno, D. Impact of information and communication technology-based market information services on smallholder farm input use and productivity: The case of Kenya. *World Dev.* **2014**, *64*, 311–321. [CrossRef]
18. Zhao, Q.; Pan, Y.; Xia, X. Internet can do help in the reduction of pesticide use by farmers: Evidence from rural China. *Environ. Sci. Pollut. Res.* **2021**, *28*, 2063–2073. [CrossRef]
19. Ma, W.; Zheng, H. Heterogeneous impacts of information technology adoption on pesticide and fertilizer expenditures: Evidence from wheat farmers in China. *Aust. J. Agric. Resour. Econ.* **2022**, *66*, 72–92. [CrossRef]
20. Zheng, H.; Ma, W.; Wang, F.; Li, G. Does internet use improve technical efficiency of banana production in China? Evidence from a selectivity-corrected analysis. *Food Policy* **2021**, *102*, 102044. [CrossRef]
21. Deng, X.; Peng, J.; Wan, C. The impact of internet use on land productivity: Evidence from China land economy survey. *Land* **2024**, *13*, 262. [CrossRef]
22. Ma, W.; Wang, X. Internet use, sustainable agricultural practices and rural incomes: Evidence from China. *Aust. J. Agric. Resour. Econ.* **2020**, *64*, 1087–1112. [CrossRef]
23. Zhang, J.; Zhang, X. The impact of internet use on the decision-making of farmland transfer and its mechanism: Evidence from the CFPS Data. *Chin. Rural. Econ.* **2020**, *3*, 57–77. (In Chinese)
24. Hu, R.; Yang, Z.; Kelly, P.; Huang, J. Agricultural extension system reform and agent time allocation in China. *China Econ. Rev.* **2009**, *20*, 303–315. [CrossRef]
25. Sun, S.; Zhang, C.; Hu, R. Determinants and overuse of pesticides in grain production: A comparison of rice, maize, and wheat in China. *China Agric. Econ. Rev.* **2020**, *12*, 367–379. [CrossRef]
26. Li, Z.; Zhang, C.; Hu, R.; Cheng, Z. Fertilizer and pesticide retailers' technology service to farmers and its effect. *China Soft Sci.* **2021**, *11*, 36–44. (In Chinese)

27. Kong, X.; Lou, D. Comparison among different countries' agricultural technology extension systems, current situations and China' s countermeasures. *Reform* **2012**, *1*, 12–23. (In Chinese)
28. Hu, R.; Wang, R.; Sun, Y.; Zhang, C. Socialized agricultural technological service and farm households' technological information source based on a survey of 2293 farm households in seven provinces. *Sci. Technol. Manag. Res.* **2019**, *39*, 99–105. (In Chinese)
29. Yan, D.; Zheng, S. Can the internet use improve farmers' production efficiency? evidence from vegetable growers in Shanxi, Hebei and Shandong provinces. *J. Nanjing Agric. Univer. Soc. Sci. Ed.* **2021**, *21*, 155–166. (In Chinese)
30. Huang, J.; Qi, L.; Chen, R. Technical information knowledge, risk preference and pesticide use by farmers. *J. Manag. World* **2008**, *5*, 71–76. (In Chinese)
31. Matanda, M.; Jenvey, V.; Phillips, J. Internet use in adulthood: Loneliness, computer anxiety and education. *Behav. Chang.* **2004**, *21*, 103–114. [CrossRef]
32. Zhang, L.; Luo, B. Agricultural Chemical Reduction: The logic and evidence based on farmland operation scale of households. *Chin. Rural Econ.* **2020**, *2*, 81–99. (In Chinese)
33. Kang, T.; Mu, Y. Asymmetry of production and marketing information and farmers' behavior of fertilizer overuse. *J. Northwest A&F Univer. Soc. Sci. Ed* **2020**, *20*, 111–119. (In Chinese)
34. Zhang, C.; Hu, R.; Shi, G.; Jin, Y.; Robson, M.G.; Huang, X. Overuse or underuse? An observation of pesticide use in China. *Sci. Total Environ.* **2015**, *538*, 1–6. [CrossRef] [PubMed]
35. Sun, S.; Hu, R.; Zhang, C. Pest control practices, information sources, and correct pesticide use: Evidence from rice production in China. *Ecol. Indic.* **2021**, *129*, 107895. [CrossRef]
36. Li, Z.; Hu, R.; Zhang, C.; Xiong, Y.; Chen, K. Governmental regulation induced pesticide retailers to provide more accurate advice on pesticide use to farmers in China. *Pest Manag. Sci.* **2022**, *78*, 184–192. [CrossRef]
37. Lin, Y.; Hu, R.; Zhang, C.; Chen, K. Effect of agricultural extension services in the post-reform era since the mid-2000s on pesticide use in China: Evidence from rice production. *Int. J. Agric. Sustain.* **2022**, *20*, 955–966. [CrossRef]
38. Lin, B.; Wang, X.; Jin, S.; Yang, W.; Li, H. Impacts of cooperative membership on rice productivity: Evidence from China. *World Dev.* **2022**, *150*, 105669. [CrossRef]
39. Ma, W.; Zheng, H.; Nnaji, A. Cooperative membership an adoption of green pest control practices: Insights from rice farmers. *Aust. J. Agric. Resour. Econ.* **2023**, *67*, 459–479. [CrossRef]
40. Maddala, G.S. *Limited-Dependent and Qualitative Variables in Econometrics*; Cambridge University Press: Cambridge, UK, 1983.
41. Zhao, J.; Zhou, D. Education human capital, internet use and career choice of the new generation of migrant workers. *Iss. Agric. Econ.* **2019**, *6*, 117–127. (In Chinese)
42. Xiao, K. A study of grain farmers internet use behavior and influence factors—An empirical research based on Henan grain farmers. *Econ. Surv.* **2012**, *6*, 32–36. (In Chinese)
43. Cui, M.; Zhang, J.; Xia, X. Effect of training on farmer' s adoption of Eco agricultural technology-The intermediary effect and masking effect. *J. Arid Land Resour. Environ.* **2021**, *35*, 38–46.
44. Kondylis, F.; Mueller, V.; Zhu, J. Seeing is believing? Evidence from an extension network experiment. *J. Dev. Econ.* **2017**, *125*, 1–20. [CrossRef]
45. Li, H.; Li, S.; Nan, L. Can technical training reduce pesticide overuse? *Chin. Rural Econ.* **2017**, *10*, 80–96. (In Chinese)
46. Zheng, J.; Zhang, R. Can outsourcing reduce pesticide overuse? Analysis based on the moderating effect of farmland scale. *J. Agrotech. Econ.* **2022**, *2*, 16–27. (In Chinese)
47. Yin, X.; Yu, Q.; Su, Q.; Li, D. The impact of internet embedding on farmers' use of chemical pesticides—Metro-logical analysis based in PSM model. *Chin. J. Agric. Resour. Reg. Plan.* **2023**, *44*, 68–76. (In Chinese)
48. Baron, R.; Kenny, D. The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *J. Pers. Soc. Psychol.* **1986**, *51*, 6. [CrossRef]
49. Luo, Q.; Zhao, Q. The impact and mechanisms of internet use on crop structure adjustment: Microscopic evidence from CRRS. *On Econ. Probl.* **2022**, *6*, 103–112. (In Chinese)