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Research on the Impact of Internet Use on Farmers' Adoption of Agricultural Socialized Services

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Abstract: Developing agricultural socialized services is of great significance for promoting agricultural sustainable development and ensuring food security. The use of the Internet provides new opportunities to promote the development of agricultural socialized services. Using data from the China Family Panel Studies (CFPS) in 2016 and 2018 with 8850 observations, this paper investigates the effects of Internet use on farmers' adoption decision and adoption degree of agricultural socialized services, and explores the mediating effect of social networks. The adoption of agricultural socialized services is divided into adoption decision and adoption degree, and the Probit model and Tobit model are used for empirical analysis. The results showed that: (1) Internet use has a significant positive impact on both the adoption decision and the adoption degree of agricultural socialized services. Specifically, the impact of Internet use on the adoption decision and adoption degree of agricultural machinery services is greater than that of agricultural hired labor services. (2) The mechanism analysis found that social networks partially mediated the effect of Internet use on farmers' adoption decision and adoption degree of agricultural socialized services. Furthermore, social networks have a greater mediating effect on the influence of Internet use on farmers' adoption decision and adoption degree of agricultural machinery services compared to agricultural hired labor services. (3) The heterogeneity test found that Internet use has no significant impact on the adoption of agricultural socialized services by older farmers and farmers with a low education level. Therefore, it is crucial to fully leverage the potential of the Internet to facilitate the supply and demand of agricultural socialized services. Moreover, it is essential to integrate the market of agricultural socialized services with the rural social network to realize the synergy of "Internet plus social network". This integration facilitates the organic connection between small farmers and modern agricultural development.

Keywords: internet use; social network; agricultural socialized services; agricultural sustainable development

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1. Introduction

China is currently undergoing a critical transition from traditional to modern agriculture [1]. With the deepening of industrialization and urbanization, as well as the unfavorable comparative returns in agriculture, a large proportion of the rural labor force has flowed out [2]. This has led to an increase in the aging and feminization of the agricultural labor force, as well as an increase in land abandonment, posing a serious threat to both food security and agricultural sustainable development. In this context, the development of agricultural socialized services has emerged as a sustainable agricultural production pattern, offering a solution to the challenges of "who will farm the land" and "how to farm the land". In recent years, the rapid development of agricultural socialized service organizations has become one of the important ways to offset the negative impact of agricultural labor shortages and small-scale decentralized operations on agricultural production [3,4]. Moreover, it has become an important organizational form for China to achieve the transformation of agricultural production and promote sustainable agricultural

development [5,6]. The Chinese government attaches great importance to the development of agricultural socialized services and has introduced a series of policies and measures to support their growth. The report of the 19th National Congress of the Communist Party of China clearly pointed out that the road to agricultural modernization with Chinese characteristics involves "improving the agricultural socialized service system and realizing the organic linkage between small farmers and modern agriculture". In 2022, the *No. 1 Document of the Central Government* once again focused on agriculture and emphasized the importance of accelerating the development of agricultural socialized services, with a particular focus on key weak links and small farmers. Given the tightening resource and environmental constraints, the development of agricultural socialized services is of great significance in achieving agricultural sustainable development.

As the main implementer of agricultural production activities, farmers undoubtedly play a crucial role in promoting the better development of agricultural socialized services. The existing literature mainly analyzes the influencing factors of farmers' adoption of agricultural socialized services from the following aspects. At the individual farmer level, the characteristics of household heads, such as gender, age, and education level, have been found to have an impact on farmers' adoption of agricultural socialized services [1]. At the household level, the influencing factors mainly include economic characteristics, such as household per capita income [7]; labor force characteristics, such as the number of household agricultural laborers and the degree of aging [8]; livelihood characteristics, such as the share of household non-farm employment and the degree of part-time employment [9]; and social capital endowment [10]. From a management perspective, factors such as the degree of land fragmentation [11], the scale of cultivated land [12,13], and topographic conditions are key considerations [14]. Regarding market supply characteristics, the source of service information [1], the service price [15], the complexity of agricultural production tasks, and the uncertainty of operation effects [16] are also key factors affecting farmers' adoption of agricultural socialized services.

However, although scholars have conducted extensive research on the factors influencing farmers' adoption of agricultural socialized services, the impact of external shocks brought about by information technology, represented by the Internet, has been ignored. According to *The 50th Statistical Report on Internet Development in China*, released by the China Internet Information Center, as of June 2022, the number of rural Internet users in China had reached 293 million, accounting for 27.9% of all Internet users. With the advancement of information technology and the promotion of the digital village strategy, the Internet has become deeply integrated with the field of agriculture, rural areas, and farmers, and has rapidly become an important channel for farmers to obtain information [17,18]. In particular, with the ongoing global COVID-19 pandemic, the importance of Internet use for people's production and lives has been further highlighted. Studies have shown that the use of the Internet can significantly promote the adoption of agricultural production technology by farmers [19]. Therefore, it is worthwhile to discuss whether the use of the Internet affects farmers' adoption of agricultural socialized services, and if so, what the underlying mechanism is.

In addition, rural China is a "relational" society based on blood and geography, and the information transmission and cohort effects condensed in social networks have an important impact on farmers' behavior and decision making [20,21]. Bandiera et al. [22] noted that social networks, as an important source of information, can significantly promote farmers' technology adoption behavior. In addition, studies have shown that Internet use not only strengthens the "strong relationship" network between farmers and their friends and relatives, but also helps farmers to build a "weak relationship" network with their online friends [23]. Therefore, this study focuses on how farmers' Internet use behavior can promote social networks among rural residents, which, in turn, increases the possibility of farmers' adoption of agricultural socialized services. Specifically, we aim to examine the relationship between farmers' Internet use and adoption of agricultural socialized services, while paying special attention to the role of farmers' social networks in enabling

this relationship. To empirically test this relationship, we utilized microdata from the China Family Panel Studies (CFPS) in 2016 and 2018.

The marginal contributions of this paper are mainly reflected in the following three aspects. Firstly, referring to the practice of Yang et al. [24], we focus on the agricultural machinery leasing services and agricultural hired labor services as the key components of agricultural socialized services. In contrast to existing literature, we analyze the adoption of agricultural socialized services by farmers from two aspects: whether farmers have adopted these services and the degree of adoption. Secondly, to address the potential endogenous problems between Internet use and the adoption of agricultural socialized services, we use a jointly estimated, conditional, mixed-process (CMP) model and an extended regression model (ERM); the empirical results are more reliable. Thirdly, we construct an analytical framework of "Internet use–social networks–farmers' adoption of agricultural socialized services" by incorporating Internet use and social networks into the same analytical framework, and we employ a mediating effect model to test the mechanism of Internet use affecting farmers' adoption of agricultural socialized services, which enriched the related research to a certain extent.

2. Theoretical Framework and Research Hypothesis

2.1. Internet Use and Adoption of Agricultural Socialized Services by Farmers

Based on the farmer behavior theory, the decision to adopt agricultural socialized services by farmers depends on the balance between adoption costs and expected income, with the maximization of benefits being the key factor. Goldfarb and Tucker [25] argue that digital technology has reduced costs in five areas: search costs, replication costs, transportation costs, tracking costs, and verification costs. As an important channel for farmers to obtain information, the use of the Internet changes the relative benefits and costs of participating in various economic activities, which has an important impact on the adoption of agricultural socialized services by farmers. Firstly, the Internet can break down the barriers of farmers' information acquisition. In social networks linked by blood and geography, information transmission within the group presents an obvious pattern of difference sequence [26]. As an information-sharing platform, the Internet can enable different farmers to obtain market information fairly and reduce information asymmetry [27,28]. Moreover, the Internet, as a service tool across time and space, can integrate and effectively allocate the existing scattered agricultural socialized services' supply bodies through farm machinery positioning and remote dispatching. This opens up the "last mile" of agricultural socialized services and promotes their adoption by farmers. Secondly, the Internet can reduce the cost for farmers to obtain service information. Constrained by the scattered market and poor rural infrastructure, both the supply and demand sides of agricultural socialized services face large information search costs. However, the embedding of Internet technology can reduce information search, negotiation, and performance costs; reduce adverse selection and moral risks caused by information asymmetry [29]; and facilitate the matching of the supply and demand sides. Aker [30] also suggests that Internet use can reduce the cost of obtaining information for farmers, enabling them to make better market decisions. Finally, the Internet can improve the efficiency of information dissemination [31,32]. The use of the Internet enables farmers to quickly obtain market information about services, such as the labor force and farm machinery. Therefore, we formulate the following hypotheses:

Hypothesis 1a. *Internet use has a significant positive impact on farmers' adoption of agricultural socialized services.*

Hypothesis 1b. *The impact of Internet use on the adoption decision and adoption degree of different agricultural socialized services is different.*

2.2. Mediating Effects of Social Networks

The Internet serves as a form of social media that facilitates communication among people and can help farmers expand their social networks, which, in turn, influence their adoption of agricultural socialized services. As a valuable social resource, social networks are primarily built through mutual communication over time. With the increasing popularity of the rural Internet, digital network technology, such as WeChat groups, QQ groups, and short videos, has been deeply embedded in every aspect of rural social production and life [33]. The Internet has shortened the spatial and temporal distance between farmers and broken down the relative isolation of traditional rural society. As a means of communication that transcends physical distance, the Internet can realize the notion of "A bosom friend afar brings a distant land near", enabling users to maintain existing strong ties and form new weak ties [34,35]. Lin [36] has pointed out that online communication can more easily generate social capital than face-to-face communication due to some unique functions of the Internet. In the current context of rural "hollowing out", which can disrupt social networks, the Internet is becoming increasingly important for providing communication opportunities and maintaining relationships [37].

The expansion of social networks plays an important role in promoting the adoption of agricultural socialized services by farmers. Firstly, a larger social network can broaden farmers' access to information, reducing the information search cost of service transactions [38,39] and mitigating the structural imbalance between the supply and demand of agricultural socialized services caused by information asymmetry. Secondly, social networks have the function of human help [40], which can promote cooperation and reciprocity among farmers. A richer social network often means that small farmers can obtain financial, technical, and labor support for adopting agricultural socialized services [41]. Finally, farmers embedded in social networks are susceptible to the influence of other members, also known as the "peer effect" [42]. For example, Goyal et al. [43] found that the use of "demonstration households" to propagate technical information can reduce the time and cost for surrounding farmers, thus promoting technology adoption [44,45]. Based on the above analysis, the expansion of social networks relies on farmers' Internet use, and social networks are an important factor affecting the adoption of agricultural socialized services by farmers. From this, we can infer that the Internet, as a social medium, can expand farmers' social networks and influence their adoption of agricultural socialized services (Figure 1). Thus, the following assumptions can be put forward:

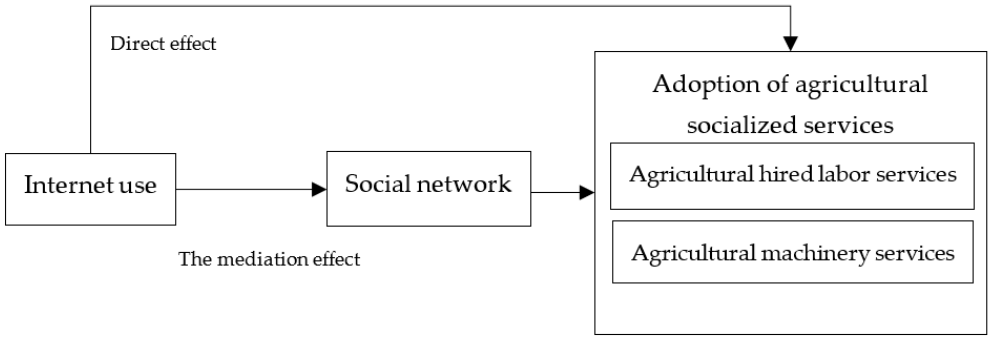

Figure 1. Theoretical analysis framework.

Hypothesis 2a. *Social networks play a mediating role in the impact of Internet use on the adoption of agricultural socialized services by farmers.*

Hypothesis 2b. *The mediating effect of social networks is different for different agricultural socialized services in terms of the adoption decision and adoption degree.*

3. Materials and Methods

3.1. Data Sources

The microdata used in this paper come from the China Family Panel Studies (CFPS), a survey program implemented by the Chinese Social Science Survey Center at Peking University. The CFPS aims to provide data support for academic research by collecting data at the individual, family, and community levels, reflecting China's social and economic development. Since 2010, the CFPS has conducted biennial surveys, with the latest publicly available data updated to 2018. The survey covers 25 provinces in China and represents 95% of the population, making it highly representative. To address significant regional differences in Chinese society, the CFPS uses a probability proportional to size (PPS) sampling method that is implicit stratified, multistage, and multilevel.

This paper employs the latest survey data from the China Family Panel Studies (CFPS) in 2016 and 2018 as the initial sample. Due to the lack of village-level information in CFPS 2016 and CFPS 2018, this study also utilizes the village data from CFPS 2014. Given that the adoption of agricultural socialized services is often determined at the household level, and this study focuses on the impact of Internet use on farmers' adoption of agricultural socialized services, we conduct our research at the household level and limit the sample to households engaged in agricultural production. We screen the sample as follows: (1) remove urban household samples; (2) exclude samples with missing key variables; (3) match and merge individual, household, and village questionnaires. After data cleaning, the final sample includes 4275 households that were surveyed in both CFPS 2016 and CFPS 2018, with a total of 8550 observations.

3.2. Variables and Measurement

3.2.1. Explained Variable

The explained variable in this study is the "adoption of agricultural socialized services", which encompasses both the adoption decision and degree of adoption. According to Yang et al. [24], mid-production services, such as agricultural machinery services and agricultural hired labor services, play a more critical role in farmers' production and management decisions than pre-production and post-production services. Therefore, this study focuses on measuring the adoption of agricultural machinery services and agricultural hired labor services in agricultural production. When farmers adopt the above agricultural socialized services, the adoption decision is assigned a value of 1; otherwise, it is assigned a value of 0. Additionally, the degree of adoption is captured by the household expenditure on agricultural machinery services and agricultural hired labor.

3.2.2. Core Explanatory Variable

The core explanatory variable examined in this study is "Internet use". Referring to Zhang et al. [23], the Internet use of the head of the household (defined as the financial respondent in the CFPS household questionnaire) was used as a measure of Internet use. The corresponding questions in the questionnaire were "whether to use computers to access the Internet" and "whether to use mobile phones to access the Internet", and for the purpose of standardization, if both answers were no, the value of Internet use was defined as 0; otherwise, it was 1.

3.2.3. Instrumental Variable

To address the potential endogenous issues arising from reverse causality or omitted variables between Internet use and the adoption of agricultural socialized services, the "Internet penetration rate", which refers to the average Internet penetration rate among rural residents in the county where the household is located, was selected as the instrumental variable [46]. The reason for selecting this instrumental variable is that, typically, the higher the Internet penetration rate in a region, the higher the likelihood of households using the Internet in that region. However, the overall proportion of Internet use at the regional level

is not directly linked to a single household's adoption of agricultural socialized services, thereby satisfying the exogenous assumption.

3.2.4. Mediating Variable

The mediating variable in this study is "social networks". Drawing on the research of Yang et al. [47], we selected expenditures on favors and gifts as a proxy variable for social networks. Rural China is a typical human society, which follows the traditional social approach of "courtesy demands reciprocity". By examine household expenditures on favors and gifts, we can objectively estimate the extent of a family's social networks.

3.2.5. Control Variable

To avoid model estimation bias arising from missing variables, referring to the research of Weng et al. [48], we selected the personal characteristics of the head of the household, i.e., gender, age, education level, and health status; family characteristics, i.e., the value of household-owned agricultural machinery, off-farm employment, land transfer, household farmland endowment, the size of the agricultural labor force, and household per capita income; and village characteristics, including the village economic level, village traffic conditions, and village topography. In addition, to reduce estimation bias, this paper also controls for region and year dummy variables. The dummy variables of eastern, middle, and western regions are set according to the province. The descriptive statistics of all variables are shown in Table 1.

Table 1. Definitions and descriptive statistics of the survey data.

Type	Variable	Definition	Mean	SD
Explained variable	Whether to adopt agricultural hired labor services	Yes = 1; no = 0	0.204	0.403
	Whether to adopt agricultural machinery services	Yes = 1; no = 0	0.481	0.499
	Expenditure on agricultural hired labor services	Take the logarithm of agricultural hired labor services expenditure (yuan)	1.483	2.994
	Expenditure on agricultural machinery services	Take the logarithm of agricultural machinery services expenditure (yuan)	3.180	3.378
Core explanatory variable	Internet use	Yes = 1; no = 0	0.269	0.443
Control variable	Gender	Gender of the head of household: 1 = male, 0 = female	0.574	0.495
	Age	Actual age of the head of household (years)	52.315	11.901
	Education level	Actual years of education of the head of household (years)	6.074	4.143
	Health status	Health level of the head of household, between 1 and 5: 1 = very healthy, 2 = healthy, 3 = average, 4 = unhealthy, 5 = very unhealthy	3.191	1.261
	Household-owned agricultural machinery	Take the logarithm of the value of household-owned agricultural machinery (yuan)	3.967	4.149
	Off-farm employment	Proportion of off-farm employment in the total labor force (%)	0.302	0.345

Table 1. *Cont.*

Type	Variable	Definition	Mean	SD
	Land transfer	Yes = 1; no = 0	0.184	0.388
	Household farmland endowment	Farmland area owned by the family (mu)	8.792	11.211
	Family agricultural labor	Number of family agricultural laborers	2.087	1.039
	Household per capita income	Take the logarithm of the annual per capita household income (yuan)	8.664	1.413
	Village economic level	Take the logarithm of the annual per capita income of the village (yuan)	6.711	3.271
	Village traffic conditions	Time from the village where the farmer is located to the county seat (hours)	3.452	8.817
	Village topography	If it is plain area = 1; otherwise = 0	0.350	0.477
Instrumental variable	Internet penetration rate	Average Internet penetration rate among rural residents in the county where the household is located (%)	0.380	0.106
Mediating variable	Social network	Take the logarithm of the expenditures for favors and gifts (yuan)	7.303	2.096

Note: 1 ha ≈ 15 mu.

3.3. Methods

First, since the adoption decision of agricultural socialized services is a binary dummy variable, this study employs a Probit model to examine the impact of Internet use on farmers' adoption decision of agricultural socialized services. The Probit model assumes the existence of a latent variable y^*, where the adoption decision takes the value of 1 if $y^* > 0$, and 0 otherwise. The expressions for the latent variable and the baseline model are as follows:

$$y_{it}^* = \alpha_0 + \alpha_1 X_{it} + \alpha_2 Z_{it} + \varepsilon_{it} \quad (1)$$

$$\text{Prob}(y_{it} = 1) = \text{Prob}(y_{it}^* > 0) = \Phi(\alpha_0 + \alpha_1 X_{it} + \alpha_2 Z_{it}) \quad (2)$$

where y_{it} is a binary dummy variable indicating whether household i adopted agricultural socialized services in year t, and the variable X_{it} denotes whether or not farmers use the Internet. Z_{it} represents a set of control variables, including the characteristics variables of the individual, household, and village, as well as the region and time dummy variables. Since the model is non-linear, the maximum likelihood method is employed for parameter estimation.

Furthermore, this paper estimates the impact of Internet use on farmers' adoption degree of agricultural socialized services through a Tobit model. The model is set as follows:

$$y_{it}^* = \beta_0 + \beta_1 X_{it} + \beta_2 Z_{it} + \varepsilon_{it} \quad (3)$$

$$y_{it} = \begin{cases} y_{it}^*, & \text{if } y_{it}^* > 0 \\ 0, & \text{if } y_{it}^* \leq 0 \end{cases} \quad (4)$$

In Equations (3) and (4), y_{it}^* is the latent variable; y_{it} is an observed variable, indicating the adoption of agricultural socialized services by households i in year t; X_{it} is the binary virtual variable of whether to use the Internet; Z_{it} is the control variables at the household head, family, and village levels; α and β are the parameters to be estimated; ε_{it} is a random error term.

In order to analyze the influence process and mechanism of how Internet use affects the adoption of agricultural socialized services among farmers, this paper empirically tests

the mediating effect of social networks using a mediating effect model. Drawing lessons from the practice of Wen et al. [49], the following mediating effect model is constructed:

$$y_{it}^{*} = c_0 + c_1 X_{it} + c_2 Z_{it} + \varepsilon_{it} \quad (5)$$

$$M_{it} = a_0 + a_1 X_{it} + a_2 Z_{it} + \delta_{it} \quad (6)$$

$$y_{it}^{*} = b_0 + b_1 M_{it} + c_1' X_{it} + b_2 Z_{it} + \mu_{it} \quad (7)$$

In Equations (5)–(7), y_{it}^{*} denotes the adoption decision and degree of agricultural socialized services; M_{it} denotes social networks; X_{it} denotes Internet use; Z_{it} denotes control variables; c, a, and b are parameters to be estimated; ε_{it}, δ_{it}, and μ_{it} are residual terms. In Equation (5), c_1 represents the total effect of Internet use on the adoption of agricultural socialized services by farmers. In Equation (6), a_1 represents the effect of Internet use on social networks. Equation (7) reflects the effect of Internet use and social networks on the adoption of agricultural socialized services by farmers, where c_1' is the direct effect of Internet use on the adoption of agricultural socialized services, and b_1 is the effect of social networks on the adoption of agricultural socialized services. When there is a mediating effect, a significant c_1' means that there is a partial mediating effect, while a non-significant result means that there is a complete mediating effect. Stata 16.0 software was used for empirical analysis

3.4. Endogenous Test

Given that the endogenous variable, Internet use, is a binary dummy variable, the IV-Probit model and IV-Tobit model are only applicable when the endogenous variable is continuous. Therefore, this paper employs the CMP model for endogeneity testing. The CMP model not only reports the correlation between instrumental variables and endogenous variables, but also provides the endogenous test parameter atanhrho_12. If atanhrho_12 is significantly different from 0, it indicates that the model has endogenous issues, and the CMP estimation result is more accurate; otherwise, it indicates that the estimation result of the benchmark model is more reliable. In order to ensure the robustness of the empirical findings, this paper further employs the extended regression model (ERM) to test the endogeneity in Section 4.2.

4. Empirical Analysis Results

4.1. Baseline Regression Analysis

Table 2 presents the impact of Internet use on farmers' decision to adopt agricultural socialized services. The results indicate a significant positive impact of Internet use on the adoption of agricultural hired labor services and agricultural machinery services. Specifically, the adoption of agricultural hired labor services is positively affected by Internet use at the 1% statistical level, with an average marginal effect of 4.1%—that is, compared to households without Internet use, households using the Internet have a 4.1% probability of adopting agricultural hired labor services. The adoption of agricultural machinery services is also positively influenced by Internet use at the 10% statistical level, with an average marginal effect of 2.5%, indicating that Internet use can increase the probability of households adopting agricultural machinery services by 2.5%. After using the instrumental variable, the results of adopting agricultural hired labor services show that the instrumental variable coefficient positively affects Internet use at the 1% significant level and, thus, satisfies the correlation. However, the atanhrho_12 parameter is not significant, indicating that Internet use is an exogenous variable. Therefore, the Probit regression results should be referred to at this point. On the other hand, the instrumental variable coefficient is significant at the 1% level for the adoption of agricultural machinery services, and the atanhrho_12 parameter is also significant, indicating that the CMP estimate is more accurate. After considering endogeneity, the effect of Internet use on whether to adopt agricultural machinery services increased to 44.6%, indicating that the positive effect of

Internet use on whether to adopt agricultural machinery services would be underestimated if endogeneity was not considered. To summarize, Hypothesis 1a and Hypothesis 1b are verified.

Table 2. Impact of Internet use on the adoption decision of agricultural socialized services.

Variable	Probit Model		CMP-IV Probit Model	
	Whether to Adopt Agricultural Hired Labor Services	**Whether to Adopt Agricultural Machinery Services**	**Whether to Adopt Agricultural Hired Labor Services**	**Whether to Adopt Agricultural Machinery Services**
Internet use	0.041 *** (0.011)	0.025 * (0.014)	0.096 ** (0.075)	0.446 *** (0.052)
Gender	−0.021 ** (0.010)	0.008 (0.011)	−0.022 ** (0.010)	−0.002 (0.010)
Age	0.000 (0.001)	0.002 *** (0.001)	0.001 (0.002)	0.010 *** (0.001)
Education level	0.006 *** (0.001)	0.004 *** (0.001)	0.006 *** (0.002)	0.004 ** (0.002)
Health status	0.006 * (0.004)	0.008 ** (0.004)	0.008 ** (0.004)	0.006 (0.004)
Household-owned agricultural machinery	0.001 (0.001)	−0.004 *** (0.001)	0.000 (0.001)	−0.005 *** (0.001)
Household farmland endowment	−0.000 (0.000)	0.000 (0.000)	−0.000 (0.000)	0.000 (0.000)
Off-farm employment	0.006 (0.014)	0.028 * (0.016)	0.022 (0.017)	0.028 * (0.017)
Land transfer	0.101 *** (0.011)	0.038 *** (0.013)	0.105 *** (0.012)	0.030 ** (0.012)
Family agricultural labor	−0.003 (0.004)	0.001 (0.005)	−0.003 (0.005)	0.001 (0.005)
Household per capita income	0.006 (0.003)	0.006 (0.004)	0.005 (0.004)	−0.002 (0.004)
Village economic level	−0.009 *** (0.002)	−0.007 *** (0.003)	−0.009 *** (0.002)	−0.005 ** (0.002)
Village traffic conditions	0.000 (0.001)	−0.002 *** (0.001)	−0.000 (0.001)	−0.002 *** (0.001)
Village topography	−0.077 *** (0.020)	0.157 *** (0.022)	−0.078 *** (0.012)	0.139 *** (0.021)
Regional effect	YES	YES	YES	YES
Year effect	YES	YES	YES	YES
N	8550	8550	8550	8550
Internet penetration rate	-	-	0.713 *** (0.051)	0.713 *** (0.051)
Atanhrho_12	-	-	−0.056	−0.542 ***

Note: *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively; the standard error of the cluster at the county level is shown in brackets. The reported results are marginal effects.

Regarding the control variables, the gender of the household head has a significant negative effect on whether to adopt agricultural hired labor services, indicating that households with female decision makers are more inclined to adopt these services due to the shortage of labor. However, gender has no significant effect on whether to adopt agricultural machinery services, but the coefficient direction is consistent with our expectations. Age has a significant positive effect on the adoption of agricultural machinery services, indicating that the older farmers tend to have weaker physical strength and, thus, require the use of agricultural machinery services. Conversely, age has no significant effect on the adoption of agricultural hired labor services. Education level has a significant positive impact on whether to adopt agricultural hired labor services and agricultural machinery services, which means that farmers with a higher education level have more opportunities for off-farm employment, thus increasing the demand for purchasing services. The lower the health level of the farmers, the more likely they are to purchase agricultural hired labor services, but this has no significant impact on the purchase of agricultural machinery services. The value of household-owned agricultural machinery has a significant negative impact on the purchase of agricultural machinery services, but has no significant impact on the purchase of agricultural hired labor services. Off-farm employment has a significant positive impact on the purchase of agricultural machinery services, as the decrease in agricultural labor caused by the increase in off-farm employment results in an increase demand for agricultural machinery services. However, off-farm employment has no significant impact on agricultural hired labor services. Land transfer has a significant positive impact on the adoption of both agricultural hired labor services and agricultural machinery services, indicating that larger-scale operations tend to purchase more services. The economic level of the villages has a significant negative impact on the adoption of both agricultural hired labor services and agricultural machinery services. This may be due to the fact that in villages with better economic conditions, farm households are more often engaged in non-farm industries, leading to a lower demand for agricultural socialized services. Village traffic conditions have a significant negative impact on the adoption of agricultural

machinery services, but have no significant effect on the adoption of agricultural hired labor services. The reason for this is that the transportation cost of agricultural machinery is high, and the farther away from the county farmers are, the more difficult it is for them to purchase agricultural machinery services. Village topography has a significant positive impact on the adoption of agricultural machinery services. Farmers in plain areas are more inclined to purchase agricultural machinery services because these areas are more suitable for large-scale agricultural machinery's continuous operation. The village landform has a significant negative impact on the adoption of agricultural hired labor services. This is mainly because agricultural mechanization is difficult to implement in non-plain areas, and traditional labor is still an indispensable and important mode of production.

Table 3 represents the impact of Internet use on the degree of adoption of agricultural socialized services. As the information conveyed by the adoption decision of agricultural socialized services as the dependent variable above may be limited, we further utilize the adoption degree of agricultural socialized services as a dependent variable to examine the effect of Internet use. The results reveal a significant positive effect of Internet use at the 1% level on farmers' adoption degree of both agricultural hired labor services and agricultural machinery services. This indicates that Internet use can significantly increase farmers' expenditure on the purchase of agricultural hired labor services and agricultural machinery services, which is consistent with the findings of other scholars [50]. After using the instrumental variable, the coefficients are significant at the 1% level, which satisfies the correlation. However, the atanhrho_12 parameter is not significant for agricultural hired labor services, indicating that there is no endogeneity of Internet use in this regression equation, so the Tobit model regression results should be considered. On the other hand, the atanhrho_12 parameter is significant for agricultural machinery services, indicating that the CMP estimate is more accurate. Thus, Hypothesis 1a and Hypothesis 1b are again verified. Specifically, farmers have overcome information access barriers through the use of the Internet, and obtained more information about the agricultural hired labor services market and agricultural machinery services market, thus promoting the adoption of agricultural socialized services. The results of the control variables are consistent with those in Table 2, so they will not be reiterated here.

Table 3. Impact of Internet use on the adoption degree of agricultural socialized services.

Variable	Tobit Model		CMP-IV Tobit Model	
	Expenditure on Agricultural Hired Labor Services	**Expenditure on Agricultural Machinery Services**	**Expenditure on Agricultural Hired Labor Services**	**Expenditure on Agricultural Machinery Services**
Internet use	1.455 *** (0.397)	0.491 *** (0.182)	0.762 ** (0.567)	4.297 *** (0.637)
Gender	−0.687 ** (0.340)	0.102 (0.153)	−0.151 ** (0.077)	−0.009 (0.090)
Age	0.003 (0.019)	0.036 *** (0.009)	0.006 (0.012)	0.097 *** (0.013)
Education level	0.208 *** (0.045)	0.057 *** (0.020)	0.045 *** (0.013)	0.038 ** (0.015)
Health status	0.197 (0.125)	0.119 ** (0.056)	0.057 ** (0.028)	0.052 (0.032)
Household-owned agricultural machinery	0.031 (0.040)	−0.033 * (0.018)	0.006 (0.009)	−0.037 *** (0.010)
Household farmland endowment	−0.000 (0.006)	0.004 (0.003)	−0.000 (0.001)	0.002 (0.001)
Off-farm employment	0.310 (0.499)	0.294 (0.224)	0.211 * (0.127)	0.341 ** (0.147)
Land transfer	3.726 *** (0.386)	0.737 *** (0.180)	0.864 *** (0.085)	0.404 *** (0.104)
Family agricultural labor	−0.056 (0.155)	0.029 (0.070)	−0.013 (0.034)	0.013 (0.040)
Household per capita income	0.208 (0.111)	0.088 (0.052)	0.038 (0.027)	−0.015 (0.033)
Village economic level	−0.312 *** (0.078)	−0.121 *** (0.035)	−0.071 *** (0.015)	−0.053 *** (0.018)
Village traffic conditions	0.003 (0.021)	−0.028 *** (0.009)	−0.001 (0.004)	−0.014 *** (0.005)
Village topography	−2.834 *** (0.677)	1.875 *** (0.304)	−0.632 *** (0.130)	1.095 *** (0.155)
Regional effect	YES	YES	YES	YES
Year effect	YES	YES	YES	YES
N	8550	8550	8550	8550
Internet penetration rate	-	-	0.713 *** (0.046)	0.713 *** (0.046)
Atanhrho_12	-	-	−0.052	−0.485 ***

Note: *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively. The standard error of the cluster at the county level is shown in brackets.

4.2. Robustness Test

This paper uses an extended regression model (ERM) to test endogeneity. Specifically, we use an extended probit regression (Eprobit) model and an extended interval regression (Eintreg) model to address the endogeneity between Internet use and farmers' adoption decision and adoption degree of agricultural socialized services, respectively. The results are shown in Table 4. The correlation coefficients of the residual terms of both whether to adopt agricultural hired labor services and agricultural hired labor services expenditure are not significant, and the original hypothesis that the model is not endogenous is supported, which is consistent with the results in Tables 2 and 3, indicating the robustness of the results. On the other hand, the correlation coefficients of the residual term for both whether to adopt agricultural machinery services and agricultural machinery services expenditure are significant. This suggests that there are endogeneity problems, and it is appropriate to use the instrumental variable method, which is still consistent with the previous research conclusions. After controlling for endogeneity, we find that Internet use has a significant positive effect on whether to adopt agricultural machinery services and the expenditure on agricultural machinery services. Thus, Hypothesis 1a and Hypothesis 1b are confirmed.

Table 4. Results of robustness test: ERM.

Variable	Whether to Adopt Agricultural Hired Labor Services (Eprobit)	Expenditure on Agricultural Hired Labor Services (Eintreg)	Whether to Adopt Agricultural Machinery Services (Eprobit)	Expenditure on Agricultural Machinery Services (Eintreg)
Internet use	0.065 * (0.050)	3.044 ** (1.795)	0.230 *** (0.039)	5.694 *** (0.815)
Residual correlation coefficient	−0.018 (0.100)	−0.043 (0.075)	−0.380 *** (0.068)	−0.388 *** (0.050)
Control variables	YES	YES	YES	YES
Regional effect	YES	YES	YES	YES
Year effect	YES	YES	YES	YES
N	8550	8550	8550	8550
Log-likelihood value	−8910.804	−14,046.310	−9792.818	−20,701.801
Wald chi2	190.46 ***	220.35 ***	1393.41 ***	1627.83 ***

Note: *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively. The standard error of the cluster at the county level is shown in brackets.

4.3. Heterogeneity Analysis

The above research has confirmed that the use of the Internet can significantly promote the adoption decision and adoption degree of agricultural socialized services. In this section, we conduct a heterogeneity analysis based on three dimensions: age, education level, and region, drawing on the method of Fan et al. [51]. The results are shown in Table 5.

Table 5. Age, education level, and regional heterogeneity.

Variable	Whether to Adopt Agricultural Hired Labor Services	Whether to Adopt Agricultural Machinery Services	Expenditure on Agricultural Hired Labor Services	Expenditure on Agricultural Machinery Services
Young families	0.147 ** (0.058)	0.159 *** (0.054)	0.335 *** (0.127)	0.357 *** (0.122)
Middle-aged families	0.236 *** (0.047)	0.107 ** (0.047)	0.601 *** (0.114)	0.331 *** (0.111)
Old families	0.145 (0.148)	−0.183 (0.141)	0.331 (0.337)	−0.253 (0.342)
Low education level	0.013 (0.090)	0.019 (0.085)	0.058 (0.188)	0.157 (0.193)
Medium education level	0.236 *** (0.069)	0.086 (0.067)	0.517 *** (0.162)	0.204 (0.156)
High education level	0.261 *** (0.051)	0.081 * (0.049)	0.649 *** (0.121)	0.231 ** (0.116)
Eastern region	0.147 ** (0.073)	−0.069 (0.068)	0.430 ** (0.168)	−0.072 (0.168)
Central region	0.200 *** (0.072)	−0.024 (0.068)	0.404 ** (0.158)	−0.076 (0.154)
Western region	0.198 *** (0.062)	0.183 *** (0.060)	0.494 *** (0.145)	0.459 *** (0.137)

Note: *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively. The standard error of the cluster at the county level is shown in brackets.

According to the age of the head of the household, the samples of the experimental group were divided into three groups: young families (under 40 years old), middle-aged families (over 41 years old and under 60 years old), and old families (over 60 years old), which were then regressed with the control group, respectively. The results showed that Internet use has a significant positive effect on both the adoption decision and adoption degree of agricultural socialized services among young and middle-aged households, while the effect on older households is not significant. This may be due to the fact that older age groups are less able to learn and have a lower level of mastery of the Internet, while middle-aged and young adults are usually able to acquire some skills in using the Internet and are more inclined to use it as a productive tool [52].

According to the education level of the head of the household, the experimental group was divided into three groups: low education level (less than 6 years), medium education level (6 years and above, but less than 9 years), and high education level (9 years and above), which were regressed with the control group, respectively. The results show that Internet use has a more significant impact on the adoption decision and adoption degree of agricultural socialized services in families with middle and high education levels, indicating that families with a higher education level can make better use of the Internet to promote the adoption of agricultural socialized services. However, families with a lower education level are prone to deviation in Internet use because of their low ability to accept new technologies and methods, which is consistent with the research conclusions of Aker et al. [53]. In addition, only 26.7% of families in this group use the Internet in the survey sample, so the impact of Internet use is not significant.

According to the area where farmers are located, the experimental group samples were divided into three groups: east, middle, and west, and regressed with the control group, respectively. The results show that Internet use has a significant positive effect on the adoption decision and adoption degree of agricultural hired labor services among households in different regions, but it only has a significant positive effect on the adoption decision and adoption degree of agricultural machinery services of households in the western region. This may be due to the fact that the western region is mostly remote and highly mountainous, with limited access to information and a less developed agricultural machinery service market. The use of the Internet has broken the geographical limitation of the trading space, and farmers can obtain market information related to agricultural machinery services in a wider range. Conversely, agricultural machinery services are common in the eastern and central plains; thus, the contribution of Internet use is not significant.

4.4. Mechanism Analysis

To verify the mechanism of the impact of Internet use on the adoption of agricultural socialized services by farmers, this paper employs a mediating effect model for analysis, and the results are shown in Table 6.

As shown in Table 6, Internet use has a positive effect on social networks at the 1% significance level, as indicated by the significant value of a_1 in Equation (5). This suggests that Internet use helps farmers to communicate at anytime and anywhere, thereby facilitating their social interactions and broadening their social networks, which is consistent with the findings of Wang et al. [37]. Column 3 shows the results after adding the mediating variable of social networks to the baseline regression model. To address the possibility of reverse causality between social networks and agricultural socialized services, which could cause endogeneity issues, this paper selects the social networks of other farmers at the village level as the instrumental variable of social networks. The reason is that the social networks of other farmers in the village can impact the size of a household's social networks, but do not directly affect the household's adoption of agricultural socialized services, thereby satisfying the instrumental variable selection criteria. This is supported by the test results related to the instrumental variable. Both Internet use and social networks in column 3 have a significant positive effect on farmers' adoption decision and adoption degree of agricultural socialized services, as indicated by the significant value of b_1 in

Equation (6). This suggests that social networks have a partially mediating effect in promoting farmers' adoption of agricultural socialized services through Internet use. In other words, farmers effectively broaden their social networks through Internet use, which, in turn, promotes their adoption of agricultural socialized services. To ensure the robustness of the results, a bootstrap (5000) test was performed, and the results were consistent with the hypothesis that the confidence interval does not contain 0. Therefore, Hypothesis 2a is proven.

Table 6. Mediating effect of social networks in the impact of Internet use on the adoption of agricultural socialized services by farmers.

Variable	**Social Networks**	**Whether to Adopt Agricultural Hired Labor Services (Direct Effect)**	**Sobel Test (z Value/*p* Value)**	**Bootstrap Test (Confidence Interval)**	**Percentage of Mediating Effect/%**
Internet use	0.221 *** (0.060)	0.055 *** (0.012)	3.274 ***	[0.0015, 0.0052]	5.723
Social networks		0.015 *** (0.002)			
Variable	**Social Networks**	**Whether to Adopt Agricultural Machinery Services (Direct Effect)**	**Sobel Test (z Value/*p* Value)**	**Bootstrap Test (Confidence Interval)**	**Percentage of Mediating Effect/%**
Internet use	0.221 *** (0.060)	0.025 * (0.014)	3.071 ***	[0.0012, 0.0048]	10.885
Social networks		0.014 *** (0.002)			
Variable	**Social Networks**	**Expenditure on Agricultural Hired Labor Services (Direct Effect)**	**Sobel Test (z Value/*p* Value)**	**Bootstrap Test (Confidence Interval)**	**Percentage of Mediating Effect/%**
Internet use	0.221 *** (0.060)	0.459 *** (0.087)	3.339 ***	[0.0126, 0.0421]	5.621
Social networks		0.124 *** (0.016)			
Variable	**Social Networks**	**Expenditure on Agricultural Machinery Services (Direct Effect)**	**Sobel Test (z Value/*p* Value)**	**Bootstrap Test (Confidence Interval)**	**Percentage of Mediating Effect/%**
Internet use	0.221 *** (0.060)	0.212 ** (0.091)	3.22 ***	[0.0104, 0.0377]	10.175
Social networks		0.109 *** (0.016)			

Note: *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively. The standard error of the cluster at the county level is shown in brackets. Due to space limitations, the results for other control variables are not included in the table and can be provided if needed.

The mediating effect of social networks on whether to adopt agricultural hired labor services is 5.723%, indicating that 5.723% of the impact of Internet use on whether to adopt agricultural hired labor services is achieved through the mediating role of social networks. In terms of whether to adopt agricultural machinery services, the mediating effect of social networks is 10.885%, indicating that 10.885% of the impact of Internet use on whether farmers adopt agricultural machinery services is realized through the mediating role of social networks. With regard to the adoption degree of agricultural hired labor services, the mediating effect of social networks in promoting farmers' agricultural hired labor services expenditure is 5.621%. In terms of the adoption degree of agricultural machinery services, the mediating effect of social networks in promoting farmers' agricultural machinery service expenditure is 10.175%. The magnitude of the mediating effect of social networks on the adoption of agricultural machinery services is greater than that of agricultural hired labor services, probably because farmers use the Internet to expand their social networks, thus broadening the sources of information related to cross-area agricultural machinery services and reducing the information cost of farmers in obtaining agricultural machinery services, ultimately promoting the adoption of agricultural machinery services. Meanwhile, the extent of farmers' adoption of agricultural hired labor services is more

strongly influenced by familiar people in the same village in their existing social relations. Therefore, Hypothesis 2b is verified.

5. Conclusions and Recommendations

5.1. Conclusions

Based on data from the CFPS in 2016 and 2018, this study explores the relationship between farmers' Internet use and the adoption of agricultural socialized services and its mechanism. The results show that Internet use has a significant positive impact on both farmers' adoption decision and adoption degree of agricultural socialized services. Specifically, we observed that the impact of Internet use on the adoption decision and adoption degree of agricultural machinery services is greater than that of agricultural hired labor services. For example, Internet use can increase the probability of households adopting agricultural hired labor services by 4.1%, while it can increase the probability of households adopting agricultural machinery services by 44.6%. Even after using the CMP estimation method to solve endogeneity and the ERM for the robustness test, the conclusion remains robust. However, the impact of Internet use is heterogeneous due to differences in farmers' ages, education levels, and regions. Specifically, Internet use significantly contributes to the adoption decision and adoption degree of agricultural hired labor services among young and middle-aged households, households with medium to high education levels, and households in different regions in China. In contrast, it only significantly contributes to the adoption decision and adoption degree of agricultural machinery services among young and middle-aged households, households with high education levels, and households in the west. Further mediating effect analysis reveals that Internet use indirectly affects farmers' adoption decision and adoption degree of agricultural socialized services by broadening their social networks. Our findings also suggest that social networks have a stronger mediating effect on the relationship between Internet use and the adoption decision and adoption degree of agricultural machinery services, compared to agricultural hired labor services. Specifically, the mediating effect values of social networks are 5.723% and 5.621% for the effect of Internet use on whether to adopt agricultural hired labor services and the hired labor services expenditure, respectively, and 10.885% and 10.175% for the effect of Internet use on whether to adopt agricultural machinery services and the agricultural machinery services expenditure, respectively.

5.2. Recommendations

This paper puts forward the following policy suggestions. Firstly, rural areas face challenges, such as high network costs and slow network speeds, which have widened the digital gap between urban and rural areas. Therefore, it is crucial to accelerate the construction of rural informatization and the digital countryside, bridging the digital gap. Furthermore, it is essential to strengthen the Internet use skills of the rural labor force through training, especially to enhance the ability of older laborers and laborers with low education levels to access and use information through the Internet. Secondly, full attention should be paid to the important role of rural social networks in the adoption of agricultural socialized services by farmers. The government should provide support to local service subjects, who can be integrated in the social networks of rural acquaintances, and leverage the advantages of acquaintances to the fullest extent. To this end, conditions can be created for the interaction and communication of farmers, and for the expansion of social networks, through the establishment of production mutual aid groups and village-level WeChat groups, among other initiatives. Finally, a comprehensive information platform for agricultural socialized services should be established to enable the integration of supply and demand. This platform can reduce transaction costs for both the supply and demand sides of the services, leading to the reasonable allocation and flow of agricultural production resources between regions.

There also exist some limitations in this study. Firstly, this study did not distinguish the impact of different methods of farmers' Internet use and the different types of information

obtained from the Internet. Secondly, we only consider the mediating variable of social networks, but other potential mediating factors may also need to be determined, which deserve further investigation. Finally, only two periods of panel data were used in this study, and future studies could obtain cross-period survey data over a longer period of time to better analyze sustainable behavior.

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