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Impact of Internet Use on Farmers' Organic Fertilizer Application Behavior under the Climate Change Context: The Role of Social Network

Qianhui Ma [1], Shaofeng Zheng [1,*] and Peng Deng [2]

[1] College of Economics and Management, Northwest A&F University, Xianyang 712100, China
[2] College of Forestry, Northwest A&F University, Xianyang 712100, China
* Correspondence: zsfeng@nwafu.edu.cn

Abstract: Climate change and global warming significantly influence farmers' activity and lead to lower production yield. To increase production without deteriorating the environment, it is vital to substitute chemical fertilizer with organic fertilizer. The utilization of organic fertilizer not only improves the soil quality but also protects the environment and helps mitigate global warming repercussions. So, there is a need to promote organic fertilizer utilization. The Internet, as an essential information medium, presently has a profound influence on farmers' production behavior. However, the relationship between Internet use and the application of organic fertilizer is explicitly sparse, especially in China. Using the survey data of 797 vegetable growers, the current study explores the impact of Internet use on farmers' organic fertilizer application behavior. The present study employs the propensity score matching (PSM) method to meet the study objective. According to the findings, it is unveiled that the Internet significantly promotes behavior towards applying organic fertilizer by approximately 10%. Further, the heterogeneity results show that the degree of impact varies due to differences in the level of education, vegetable farming income, and the number of vegetable laborers in the family. Moreover, social networks are also used to explore the nexus between the Internet and organic fertilizer application. The findings reveal that social networks favorably play the mediating role. The overall results propose that policymakers should establish the Internet infrastructure and an official online platform to help farmers consolidate and extend the scale of their social networks and exchange information more conveniently to improve their ability to apply environment-friendly production technology.

Keywords: Internet use; organic fertilizer application; propensity score matching (PSM) method; mediating effect model; farmer

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1. Introduction

Climate change, especially global warming, is of grave concern worldwide [1]. Global warming has exacerbated economic inequality among countries [2], intensified the soil's moisture loss, and damaged agriculture production activities, mainly in developing countries with poor infrastructure. Greenhouse gas emissions mainly cause global warming. In the agricultural sector, nitrogen fertilizer, a chemical fertilizer, contaminates the water, and induces soil degradation and greenhouse gas emissions, if used excessively [3–9]. Therefore, reducing the chemical fertilizer application is recommended to improve the environment and the air quality.

In China, the vegetable industry has enormous production intensity and occupies a more significant proportion of the world's vegetable production. Besides the vast output, the excessive application of chemical fertilizer is a severe concern in the vegetable industry in China [10]. A recent report found that China is more heavily reliant on fertilizers than any other developed country [6,11,12]. Thus, China's central committee has proposed several policies to amend this rising issue, and one of the most crucial initiatives is substituting chemical fertilizers with organic ones.

Organic fertilizer is a material with rich carbon content mainly derived from animals and plants [13]. It contains more nutritional content as compared to chemical fertilizer [14]. It is also regarded as a sound agricultural technology that can increase production without harnessing the environment [5,14]. It effectively alleviates agricultural non-point source pollution and improves the soil's quality [10,15]. More specifically, it improves soil fertility, soil conditions, and the communities of the soil microbial [10]. Furthermore, it alleviates soil acidification and compaction [12], enhances the carbon dioxide uptake in the land, and reduces greenhouse gas emissions [16]. Therefore, it is imperative to encourage farmers to replace chemical fertilizers with organic fertilizers.

However, the main disadvantage of organic fertilizer is that it requires long-term investment with lower returns in the short term and more labor and money than chemical fertilizer [6,15]. Thus, developing countries' farmers prefer chemical fertilizer over organic fertilizer [6]. The study of Lu et al. [15] showed that the application rate of organic fertilizer in China is considerably lower than in most developed countries. Moreover, according to the data from the United Nations' Food and Agriculture Organization, it is shown that China has been among the nations that are less reliant on organic fertilizers but heavily dependent on chemical fertilizers since 1984 [13]. Hence, it is desirable to explore the factors influencing farmers' adoption of organic fertilizers. There is a need to find a feasible path to incentivize farmers to adopt organic fertilizer to boost sustainable development in agriculture.

Many studies have elucidated the factors influencing farmers' organic fertilizer application behavior in the prevailing literature. For instance, some studies found that individual characteristics, such as gender [17], education level [12], age [18], and non-agricultural employment [19] affect farmers' organic fertilizer application. Some scholars emphasized the effect of household-level features, including farm size [20] and the stability of the land [21]. Additionally, some research stated external factors, such as laws and regulations [6,22], land policies [23], and social norms [24]. Moreover, capital endowment characteristics were also taken into consideration, such as social capital [25]. Furthermore, psychological variables based on the prospect theory, field theory, attachment theory, and normative activation theory were discussed, including risk attitude [26,27], environmental cognition [28,29], farmers' understanding of the consequences, and their awareness of responsibility [11].

On the other side, information is also found to influence farmers' agricultural production behavior [24,30,31]. For instance, several studies reported that information access is indispensable to farmers' market participation and agricultural production activities [32–36]. Zhang et al. [37] revealed that the Internet and information technology significantly boost agricultural income. Likewise, Bruno et al. [38] also explored the phenomenon of information networks and farmers' new technology adoption behavior. According to their study, it is found that information-related variables have a more significant impact on technology adoption than other variables, such as farmers' characteristics and farm characteristics. However, as an essential modern information acquisition channel, the previous research has not concentrated on exploring the relationship between Internet use and organic fertilizer application behavior.

Moreover, it is also known that the Internet reduces information-seeking costs and information asymmetry with the rapid development of the digital economy [39]. Internet users can access information quickly. In the context of China, it is found that the number of Internet users in China had reached 1.051 billion by the end of June 2022 [40]. Moreover, in rural areas of China, the Internet users also spiked to 0.284 billion, which reflects the speed diffusion of Internet technology in rural areas of China since December 2020 [41].

Therefore, it is unveiled that the Internet profoundly impacts agriculture and farmers. Recently the research on Internet use and agricultural production has attracted the attention of scholars. In this regard, many studies have been conducted, such as Zheng et al. [39] found that the Internet improves the input efficiency of the farmers, modifies farmers' production behavior, and reduces their transaction costs by improving their bargaining power. Similarly, Heidi and Finn [42] used panel data and found that the Internet improves productivity through efficient fertilizer use. Moreover, in the context of the ecological environment, Li et al. [43] showed that the Internet positively and significantly influences farmers' conservation practices by enhancing their awareness regarding environmental protection. Yang et al. [44] also indicated that the Internet dramatically affects farmers' adaptive behavior by altering their perceptions. Similarly, Deng et al. [45] also concluded that the Internet improves farmers' perception of environmental pollution.

Some other studies also conducted the mediation analysis to explore the link between the Internet and organic fertilizers application. In this regard, Yuan et al. [5] used human capital to mediate the relationship between Internet use and chemical fertilizer adoption. Deng et al. [46] also revealed human capital as a mechanism between the Internet and cropland abandonment. Zhao et al. [47] analyzed the effect of the Internet on the reduction of pesticide use through multiple mediating effects, such as the acquisition, the perception of green production, and the capability to engage in e-commerce sales.

However, studies exploring the relationship between Internet use, social networks, and organic fertilizer application are sparse, especially in the context of China. Moreover, the previous literature has rarely focused on the mediation effect of the different dimensions of social networks. Unlike previous works, the current study explores the phenomenon by employing strong and weak ties as a mediator for social networks. Previous studies revealed that the Internet can consolidate farmers' strong and weak social network ties [37]. The stronger ties include relationships with relatives and friends, and weak ties encompass relationships with strangers.

So the current study explores the Internet's impact on the application of organic fertilizer and also analyzes the mediation role of social networks in the context of China. We aim to address the main research question of whether and how Internet use influences farmers' organic fertilizer application behavior. Considering the self-selection problem of farmers' using the Internet and the sample selection bias in the analysis, the study employs the propensity score matching (PSM) method to build a counterfactual framework to solve the potential endogenous problem according to previous research [12,37]. The results may provide a possible path to promote the substitution of chemical fertilizer with organic fertilizer, and further realize agricultural low-carbon and sustainable development goals to meet climate change challenges. The study contributes to the literature in the following ways. Firstly, combining information economic theory and the farmer's behavior theory, the study explores the impact of Internet use on farmers' organic fertilizer application behavior. Secondly, unlike the study of Yuan et al. [5] and Deng et al. [45], who used human capital as a mediator, the current research uses social networks and their two dimensions (strong and weak ties) to analyze the phenomenon. Thirdly, the study explores the influence of Internet use on the organic application behavior of farmers based on different characteristics, including education level, vegetable farming income, and amount of vegetable growing labor.

The remainder of the study proceeds as follows. We first present the research background in Section 2. Section 3 presents the theoretical analysis and proposes the hypothesis. Section 4 covers the data source and method. The results and discussion are presented in Section 5. Section 6 concludes and draws some policy implications. Finally, the limitations are discussed in Section 7.

2. Research Background

China is located in the northwest of the Pacific area and is more profoundly influenced by climate change than other countries globally [46,47]. Climate change, such as global warming and other extreme weather events, is a natural risk that farmers confront during agricultural production [48–52]. Therefore, China needs to reduce greenhouse gas emissions in the agriculture sector by promoting technological innovation activities. Based on this, the Chinese government initiated the "zero increase of chemical fertilizers" and the action plan of "substituting organic fertilizer with chemical fertilizer in fruits, vegetables and tea" in 2015 and 2017, respectively. The initiative aimed to reduce the carbon dioxide and N_2O emissions in agricultural production and cope with the challenges of global warming.

However, the application rate of organic fertilizer in China is still relatively low [5]. Recently the era of the digital economy has influenced Chinese rural families [48] and facilitated them to share production and life risk scenarios among the community. Hence, exploring the effective mechanism of Internet use and organic fertilizer application behavior is valuable.

In this study, we selected Shouguang city of Shandong Province as our sample area due to the following aspects: firstly, Shouguang city is located in the central of the Shandong Peninsula in China, and it has the temperate monsoon weather characteristic. There is little rain in spring, winter, and autumn, and the weather is hot in summer. So, this region is easily susceptible to global warming and soil moisture and nutrient loss, which entices farmers to apply an organic fertilizer to conserve soil fertility. Secondly, Shouguang city is also called the "hometown of vegetables" because it has a huge base for vegetable production and sales in China. Thirdly, the government has considerably emphasized agricultural product quality and safety due to the developed vegetable production industry. In this regard, vegetable growers are trained to opt for organic fertilizer applications and Internet use. Therefore, Shouguang city is a good representative research area.

3. Theoretical Analysis and Hypothesis Proposal

3.1. The Direct Impact of Internet Use on Farmers' Organic Fertilizer Application Behavior

Organic fertilizer is a technology adoption behavior, and information in this regard plays an essential role in diffusing technology among farmers [53–56]. Thus, as a vital information medium, the Internet can break the time and distance barriers and allows its users to acquire information quickly and accurately at a lower cost [50–52,57–59]. Therefore, the Internet influences farmers' organic fertilizer application behavior through the following three aspects.

Firstly, farmers usually do not know much more about their agricultural products' price and sales channels, which induces their lower bargaining power in the process of production and selling [60]. Then, they cannot sell organic agricultural products at a good price, therefore, they have insufficient enthusiasm to apply organic fertilizers to vegetables. However, the Internet has successfully helped farmers search for the accurate price information they need [61]. Moreover, the Internet also raised their bargaining power to sell agricultural products produced using organic fertilizer at a reasonable price. Therefore, it can promote farmers' utilization of organic fertilizers.

Secondly, environmental protection cognition and awareness are vital to changing human behavior [28,37]. In addition, humans tend to pay more attention to negative phenomena than positive ones, which have a more significant influence on humans than the latter [43,62]. Modern technology these days provides information in the form of pictures and videos that enable farmers to easily understand the damage caused to the environment by excessive utilization of chemical fertilizers and incentivize them to use organic fertilizer. Moreover, external factors are also imperative to changing farmers' behavior, such as the government's regulation and subsidies [5,63], which can be obtained from the Internet. In this regard, the Internet also promotes the application of organic fertilizer to farmers.

Thirdly, the Internet is an important educational tool [52,64] and a source of knowledge these days [65,66]. The Internet provides information and knowledge through diverse forms such as videos, pictures, and words. These forms are conducive to conveying more easily understood knowledge to farmers about the technical usage of organic fertilizer. Therefore, farmers can improve their organic fertilizer application ability during the learning process. On the other hand, the Internet is a good platform for gathering mass information from many kinds of sources, in which farmers can search for the knowledge they need quickly and conveniently. The more knowledge farmers obtain, the higher level of modern production skills they may attain [67], which promotes their organic fertilizer application.

Therefore, this study proposes the following hypothesis:

H1: *Internet usage significantly and positively influences farmers' organic fertilizer usage behavior*.

3.2. The Mediating Effect of Social Networks on Farmers' Organic Fertilizer Application Behavior

The "relationship-oriented" characteristic is one feature of Chinese society [57]. Chinese rural society is also an "acquaintance society". Social networks are a kind of relationship [68] that reflects the richness of individuals' social relations to some extent. It is a set of connections with social members who share various resources in this relational system [69–72]. Additionally, Social networks influence farmers' behavior largely [73,74]. It can not only decrease the technology adoption cost [75] but also influence farmers' information flow destination [76]. Moreover, organic fertilizer application is also a kind of technology adoption. Therefore, social networks can generally influence farmers' organic fertilizer application behavior [77]. Specifically, on the one hand, the technology adoption process can be regarded as a process of dynamic learning and imitation [54,78]. In this regard, individuals often prefer to imitate the behaviors of people around them [57,79]. The process of learning and imitation is inseparable from information and knowledge. Information and knowledge diffusion are highly dependent on connections and interactions between farmers [70,80]. Farmers regard other farmers who are close to them as reliable and trusted sources of information and knowledge [56,81]. Social networks enrich farmers' knowledge and experience by mutually participating in agricultural activities [75,76]. Hence, farmers can quickly learn to curtail the difficulties while applying organic fertilizer. On the other hand, social networks are also an effective means of reducing farmers' production risk [82]. It can help farmers solve the problems that occur during the new technology adoption process. Therefore, social networks are considered crucial in adopting organic fertilizer application behavior.

Moreover, according to Granovetter's theory, social networks are classified as solid network ties and weak network ties [83]. Each has its characteristics, both positive and negative [84]. Strong ties are attributed to the link among members with the same features such as lifestyle, education, and knowledge levels such as friends, relatives, and family members. They trust each other deeply, provide emotional and financial support, and can also provide knowledge of technology at any time. They are closer to each other compared with weak network ties. In contrast, weak ties equip farmers with heterogeneous information as the individuals belong to different backgrounds [83,85].

As an essential modern information medium, the Internet enables farmers to contact their social network more conveniently than by telephone [42] and communicate with each other in abundant forms. At the same time, the Internet provides many platforms such as social media [70] for farmers to recognize more friends who are planting the same crops or agricultural technology experts and establish weak ties with them. Social media is widely used in the agricultural sector and can be defined as a kind of Internet communication platform that lets farmers share and exchange extensive knowledge easily [70,86,87]. Therefore, the Internet can consolidate both strong relations and expand the scale of weak network ties [57,88–90]. Following the discussion, the current study proposes the following hypotheses:

H2: *Social networks mediate the relationship between Internet use and organic fertilizer adoption behavior*.

H2-1: *Strong social network ties mediate the relationship between Internet use and organic fertilizer application behavior*.

H2-2: *Weak social network ties mediate the relationship between Internet use and organic fertilizer application behavior*.

4. Data and Methods

4.1. Survey Site

Shouguang city of Shandong province in China was selected as the study site. It has a total area of 2180 square kilometers, which is located at 118°32′~119°10′ east longitude and 36°41′~37°19′ north latitude, and has a long history of vegetable planting (Figure 1). It is home to the largest wholesale vegetable market that distributes vegetables to the rest of China. Additionally, Shouguang city has the strength of planting vegetables with green certification. Therefore, compared with other areas in China, organic fertilizer has been more widely applied by vegetable growers.

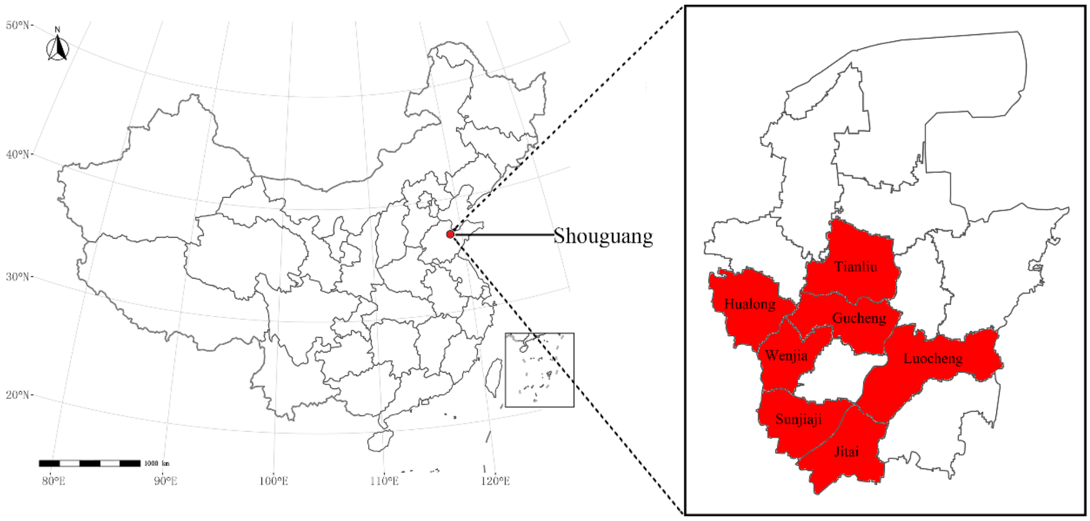

Figure 1. Map of survey site.

4.2. Sample Selection

The data are from a field survey conducted by the research group from 18 September to 30 September 2019. The research team employed both simple random and stratified sampling. The process of the sampling was as follows. Firstly, seven towns in the city, specifically Hualong, Tianliu, SunJiaji, Luocheng, Gucheng, Jitai, and Wenjia were selected randomly. Then, we chose six to eight villages in each town. Additionally, 10 to 15 farmers were selected from each village. The face-to-face indoor survey method was conducted to obtain factual and accurate information. Moreover, the research team was trained sufficiently before the survey to ask the questions in a way the respondents quickly understand. Finally, a total of 801 vegetable growers were interviewed. After excluding the missing data and incorrect information, a total of 797 questionnaires were retained for empirical analysis. The effective response rate of the questionnaire was as high as 99.50%.

4.3. Variable Selection

4.3.1. Dependent Variable

Organic fertilizer application is the dependent variable in this paper, which is measured as a dummy variable by following existing literature [11,25]. The value is assigned one, if a farmer applies organic fertilizer; otherwise, zero.

4.3.2. Core Independent Variable

The core independent variable in this study is Internet use, a relatively broad concept. In order to reflect the effect of Internet use on farmers' agricultural production, based on previous studies [38,91], the current study defines the independent variable as whether farmers use the Internet to search for agricultural production information. The assigned value is one if the answer is yes; otherwise, zero.

4.3.3. Mediation Variable

The mediator in this article is social network. Referring to the previous literature [86], the current study employs social network as a mediator that includes solid and weak social network ties. Strong ties reflect a closer relationship with family and friends they trust deeply. In China, farmers' willingness to help others indicates their intimacy in the relationship. Therefore, following Sun et al. [92], strong ties are measured on a 5-point Likert scale to reflect the extent to which farmers receive help from others. In addition, following the study of Xie et al. [11], Sun et al. [92], Xu et al. [93], Bao et al. [72], and the reality in rural areas, weak ties are measured based on the number of mobile phone contacts except for people who often contact and provide help to farmers. Weak ties are also measured on a 5-point Likert scale.

4.3.4. Control Variables

Following prior studies [9] and the data accessibility, control variables are also employed in the study, which include individual-level characteristics, such as the gender, age, and education degree of farmers; family-level aspects, such as whether the head of the family has a part-time job, whether the family has the village cadre, the number of vegetable growing laborers, the proportion of off-farm laborers in the family and the family income from planting vegetables; the planting aspects of the family, such as the number of years spending on producing the vegetables and the vegetable planting area; and the external environmental conditions, such as the distance from the farmer's home to the township government and the distance from home to the nearest market.

The definition and the statistical description are shown in Table 1.

Table 1. Variable definition and statistical description.

Variable Type	Variables	Variable Description	Mean	S.D.	Min	Max
Dependent variable	Organic fertilizer behavior	Employ organic fertilizer. 1 = Yes; 0 = No	0.6039	0.4568	0	1
Main independent variable	Internet use	Use the Internet to obtain agricultural information. 1 = Yes; 0 = No	0.4943	0.5003	0	1
Mediation variables	Strong ties	The degree of farmers getting help from others: 1 = rarely, 2 = less, 3 = generally, 4 = more, 5 = very much	3.5947	1.0212	1	5
	Weak ties	The degree of mobile phone contact number except for people who often contact and provide help to farmers: 1 = rarely, 2 = less, 3 = generally, 4 = more, 5 = very much	2.8557	1.6018	1	5
Control variables	Gender	1 = Male, 0 = Female	0.6048	0.4892	0	1
	Age	The age of the farmer	51.4103	8.8274	28	83
	Education	The years of farmers accepting the education	7.7930	2.9601	0	20
	Part-time job	The head of the family has a part-time job. 1 = Yes; 0 = No	0.1167	0.3212	0	1
	Village cadre	The family has a village cadre. 1 = Yes; 0 = No	0.0816	0.2739	0	1
	Vegetable labor	The number of vegetable labors in the family	2.1568	0.6510	1	6

Table 1. *Cont.*

Variable Type	Variables	Variable Description	Mean	S.D.	Min	Max
	Off-farming labor proportion	The proportion of off-farming laborers in the family	0.2423	0.3262	0	0.8
	Income	The family income from planting vegetables	13.9883	11.6218	0.32	100
	Year	The number of years planting vegetables	19.9260	10.1619	1	59
	Vegetable planting area	The total area of vegetable planting	3.9529	5.2391	0.5	70
	Distance to government	The distance from home to the township government (kilometers)	3.4513	7.0399	0.5	54
	Distance to market	The distance from home to the nearest market (kilometers)	0.9954	3.1937	0	50

4.4. Model Selection

4.4.1. Propensity Score Matching Method (PSM)

Since Internet use is not random behavior, this study may have a self-selection problem. In addition, farmers have different characteristics, and the degree of the impact of the Internet on their organic fertilizer application behavior also varies based on their characteristics, which may lead to selection bias. So to fix this issue, the current study employs the PSM to establish the counter-factual framework. Simply put, this method matches many characteristics of a treatment member and a non-treatment member based on the propensity scores of those participating in the treatment group [94].

The process of this method is as follows [94]. Firstly, according to the estimation, farmers (using the Internet or not) are classified into two groups (a treatment group and a control group). Secondly, a test of the common support area and matching balance degree is carried out to ensure the matching quality. Thirdly, the difference in the impact of the Internet on organic fertilizer application behavior is analyzed in the two groups by calculating the average treatment effects of the treatment group.

The specific model is as follows:

$$PS_i = Prob(N_i = 1|D_i) = E(N_i = 0|D_i) \quad (1)$$

$$\text{ATT} = E(y_{1i}|N_i = 1) - E(y_{0i}|N_i = 1) = E(y_{1i} - y_{0i}|N_i = 1) \quad (2)$$

In Equations (1) and (2), i denotes farmer i; N_i = 1 represents the use of the Internet, otherwise N_i = 0. D_i represents the control variables. In Equation (2), y_{1i} is the organic fertilizer application behavior of farmers using the Internet, who are in the treatment group, and y_{0i} is the organic fertilizer application behavior of farmers matched with farmers using the Internet. These farmers are in the control group $E(y_{1i}|N_i = 1)$ can be observed directly, whereas $E(y_{0i}|N_i = 1)$ cannot be observed.

4.4.2. Mediating Effect Model

The study further employs the mediation model to analyze the role of social networks in influencing, via the Internet, farmers' organic fertilizer application behavior. Following the approach of Wen and Ye [95], the stepwise mediation model is as follows in Equations (3)–(5):

$$Y_i = a_1 INF_i + a_2 X_i + \varepsilon_i \quad (3)$$

$$M_i = a_0 + a_3 INF_i + a_4 X_i + \varepsilon_i \quad (4)$$

$$Y_i = a_5 INF_i + a_6 M_i + a_7 X_i + \varepsilon_i \quad (5)$$

In Equations (3)–(5), INF_i is the core independent variable, M_i is the mediating variable, and X_i represents the control variables.

5. Results and Discussion

5.1. Factors of Farmers' Decisions Regarding Internet Use

According to the previous study of the PSM procedure [67,96], this study first employs the Logit model to explore the factors of farmers' decision to use the Internet. The results indicate that gender, education, whether the family has a village cadre, the planting year of vegetables, and the distance from the family to the government are all significantly and positively at 5% and 1% levels (Table 2). It infers that farmers with characteristics such as being male farmers with higher education levels and their families have a village cadre, and those more experienced in planting, as well as are more distant from their family and the government are more likely to use the Internet. Meanwhile, farmers' age significantly and negatively influences Internet use decisions at a 1% significance level. The results indicate that the older the farmer, the less they are inclined to use the Internet.

Table 2. Logit model estimation results of farmers' decisions regarding Internet use.

Variables	Coefficient	S.E.	Z-Statistics	*p*-Value
Gender	0.4100 **	0.1723	2.38	0.017
Age	−0.1100 ***	0.0128	−8.58	0.000
Education	0.1341 ***	0.0318	4.21	0.000
Part-time job	0.1966	0.2603	0.76	0.450
Village cadre	0.8235 **	0.3317	2.48	0.013
Vegetable labor	−0.0120	0.1350	−0.09	0.929
Off-farming labor proportion	−0.2109	0.2616	−0.81	0.420
Year	0.0572 ***	0.0100	5.92	0.000
Income	0.0043	0.0085	0.50	0.616
Vegetable planting area	0.0120	0.0189	0.63	0.529
Distance to government	0.0663 ***	0.0193	3.44	0.001
Distance to market	−0.0110	0.0262	−0.42	0.674
Sample size		797		
Log Likelihood		−453.4895		
LR2 (12)		197.80		
Prob > χ^2		0.000		
Pseudo R^2		0.1790		

Note: The significance level at 1%, 5% are represented by asterisk ***, **, respectively.

The findings infer that according to the Chinese rural reality background, compared with female farmers, male farmers have more opportunities to accept novelties because they can always work farther from home than women and encounter new things such as the Internet. Therefore, male farmers are more likely to use the Internet to obtain agricultural information. This result is consistent with previous literature [44,46]. Likewise, farmers with more education are more inclined to use the Internet to gain updated information and knowledge. Previous studies also stated that farmers with higher education often have a higher level of capability to search for information [49,97]. Moreover, families with a village cadre can easily obtain updated government policies related information and easily find information using the Internet. This result is consistent with Cai et al. [98]. The vegetable planting year reflects the experience of planting vegetables, the more experience farmers have, the more probability for the farmers to obtain updated and innovative information regarding adoption via the Internet. This result is contrary to the research of Cai et al. [98]. However, one of the findings above shows that the distance from the farmers' families to the local government's site positively influences the farmers' Internet use. This result is similar to the research on the effect of distance to the nearest local market on Internet use [67]. One probable explanation is that if farmers' families are distant from the government, getting information from good sources is inconvenient, so they tend to get the information online.

5.2. Test of Common Support and Matching Balancing

To ensure and examine the reliability of the PSM, two essential principles are established to test the matching quality: firstly, the overlap interval area which reflects the propensity scores of the treatment group and the control group; and, secondly, the balance test. It demonstrates the difference in the treatment group's and the control group's characteristics before and after the matching. Moreover, the larger the overlap area, the better the matching quality; and, the lower the degree of the difference's significance, the higher the quality level of the matching. The results of the common support area and matching balance test are portrayed in Figure 2, Figure 3, Figure 4 and Table 3. Figure 2a,b shows that the overlap area is larger after matching, which indicates that the matching quality is credible. In detail, the interval of the common support area is [0.0716, 0.9203]. Moreover, the number of observations lost is also minimal after matching (Figure 3).

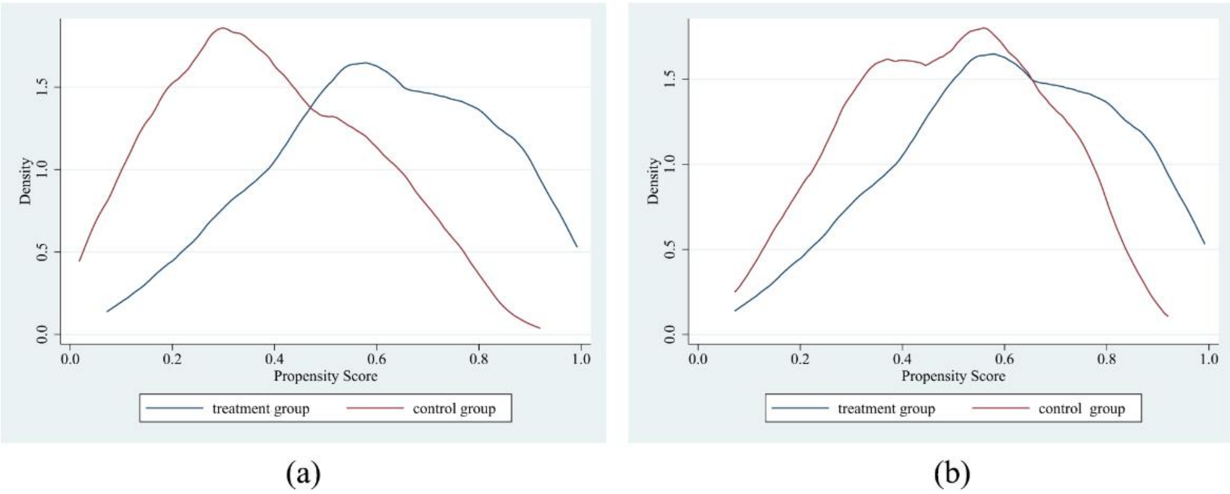

Figure 2. Propensity score probability density map. (**a**) before matching (**b**) after matching.

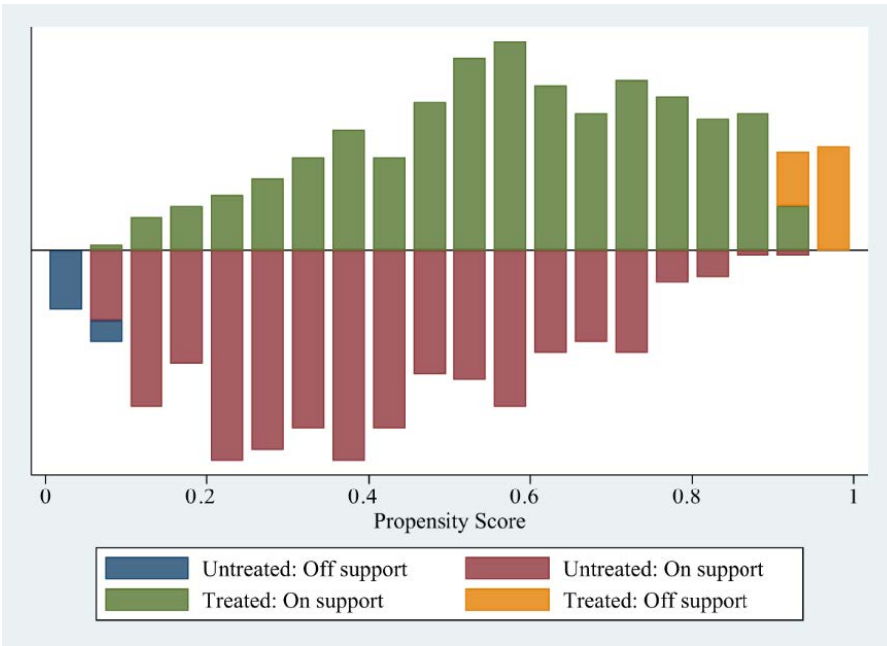

Figure 3. The common support region of propensity score. To ensure the robustness of the matching result, this study further employs the three matching methods, specifically k-nearest neighbor matching (K = 3), k-nearest neighbor matching (k = 4), and kernel matching (window width = 0.06), and the support areas of each method are found similar.

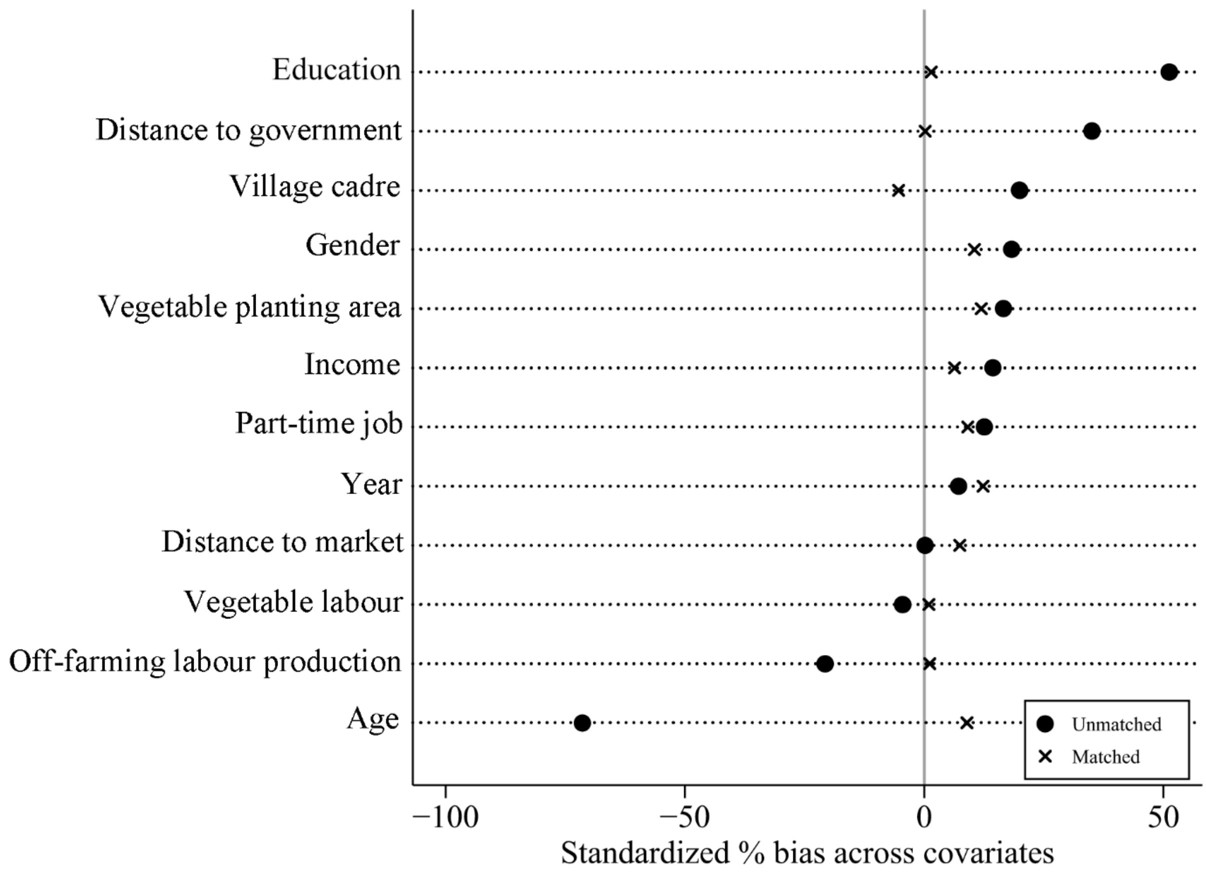

Figure 4. Standardized bias of covariates.

Table 3. Balance test results.

Sample	Pseudo R^2	LR Statistics	p > chi2	Bias of Mean	Bias of Median
Unmatched	0.180	198.69	0.000	22.7	17.4
Matched	0.012	11.88	0.455	6.3	6.9

Table 3 and Figure 4 show the balance test results and indicate that most of the variables' standard bias is lower than the value before matching. Moreover, the pseudo-R^2 is significant after matching, and the LR statistics' value decreases substantially from 198.69 to 11.88, suggesting that the matching results are robust.

5.3. Impact of Internet Use on Organic Fertilizer Application Behavior

5.3.1. Effect of Internet Use on Organic Fertilizer Application Behavior

With the help of the PSM, the impact of Internet use on organic fertilizer application behavior is shown in Table 4. Column 1 contains the matching methods, which are k-nearest neighbor matching (K = 3), k-nearest neighbor matching (k = 4), and kernel matching (window width = 0.06). Columns 2 and 3, respectively, represent the coefficient of the effect of Internet use on organic fertilizer application behavior in the treatment group and the control group. The results of the average treatment effect on the treated (ATT) are indicated in the fourth column. It suggests that the Internet positively affects farmers' organic fertilizer application behavior at 5% and 10% significance levels. The results suggest that the higher the educational level of farmers using the Internet, the greater the probability of them applying organic fertilizer, and the probability value is about 10%. Therefore, assumption H1 is confirmed. The results correspond well with several previous studies [5,12,43,88].

Table 4. Treatment effect of Internet use on organic fertilizer application.

Matching Methods	Treated Group	Control Group	ATT
k-nearest neighbor matching (K = 3)	0.7452	0.6265	0.1187 **
k-nearest neighbor matching (k = 4)	0.7452	0.6322	0.1130 **
Kernel matching (window width = 0.06)	0.7452	0.6623	0.0830 *

Note: The significance level at 5%, 10% are represented by asterisk **, *, respectively. The number of repeated sampling of Bootstrap (obtaining the significance test result of ATT) was 500 times.

Moreover, according to information economy theory, information plays a vital role in agriculture production and farmers' decision [99]. As the information is considered a tool to reduce the uncertainty and risk in the production process to some degree, the quality and effectiveness of information are crucial for farmers to access. In this regard, the Internet is regarded as a modern mode of information that can quickly transmit enriched information at a low cost [45] and alleviate information asymmetry [12]. Therefore, in the context of production, farmers can improve their knowledge and perception regarding environmental protection [12,100], and, at the same time, gain more skills in the application of organic fertilizers [12,49]. This boosts human capital [53] and hence increases the utilization of organic fertilizers. In the context of selling, the Internet can help farmers know more about the consumer's demand and the price of organic agricultural products [101,102], which leads them to increase their expectations and bargaining power [103,104] and eventually track the increased utilization of organic fertilizers.

5.3.2. Treatment Effect of Different Characteristics of Farmers

The heterogeneity analysis of the impact of Internet use on organic fertilizer application behavior is shown in Table 5. Considering the farmers' diverse characteristics, the study finds average value as the dividend [47] to further divide the farmers into two groups based on the difference in characteristics. It is apparent that Internet use significantly influences the organic fertilizer application behavior of higher-educated farmers at a 5% significance level. The result reveals that farmers with higher education levels are more inclined to use the Internet and opt for organic fertilizer. Some other researchers also demonstrate that farmers with higher education are more capable of searching for the information they need via the Internet and applying it to production activity to improve production [42,52,53,94]. Moreover, Internet use significantly and positively influences farmers with less vegetable farming income at a 10% statistical level. The finding indicates that the Internet affects farmers with less revenue from vegetable planting. It infers that farmers with lower vegetable farming income are inclined to gain information on modern technology adoption via low-cost information sources. These farmers ponder the Internet as a costless tool to access information. However, farmers with more income may have many opportunities and channels, not just the Internet, to get information and guidance due to their economic strength. Zheng et al. [53] and Deng et al. [46] also exhibited the same phenomenon and concluded the same findings. Additionally, in the context of farmers' families with more vegetable planting labor, the outcome unveils that these farmers are more likely to apply organic fertilizers after using the Internet. This result is significant at a 10% level. Furthermore, families with more laborers are more potential to live on vegetable planting. Therefore, on one side, farmers in this group attach more importance to improving vegetable planting technology and spend more time seeking updated information via the Internet. On the other side, the age structure of these farmers' families is more diverse, and these families may be more capable of applying the information to agricultural production. Zheng et al. [91] also stated similar opinions.

Moreover, many researchers also discussed the influence of Internet use on farmers' production behavior based on the diverse characteristics of the farmers [53,91,101]. The heterogeneity analysis proves the significant positive effect of Internet use on farmers' organic fertilizer application behavior. It reveals that the impact is significantly different among farmers with varying levels of education, vegetable income, and the number of vegetable laborers in the family.

Table 5. Analysis results of the impact of Internet use on farmers' organic fertilizer application behavior with different characteristics.

Group Variables		Treated	Control	ATT
Farmers education level	Above the average	0.7491	0.6262	0.1229 **
	Below the average	0.7108	0.6806	0.0302
Vegetable farming income	Above the average	0.8203	0.8075	0.0128
	Below the average	0.7033	0.6039	0.0995 *
Amount of vegetable planting labor	Above the average	0.7290	0.6469	0.0821 *
	Below the average	0.8611	0.7407	0.1204

Note: The significance level at 5%, 10% are represented by asterisk **, *, respectively.

5.4. Mediation Effect of Social Networks

Chinese rural society is a representative "acquaintance society" [72,105]. Social networks play an important role in farmers' production decision-making [70]. Moreover, social network theory states that social networks are classified as solid network ties and weak network ties. Therefore, this study empirically explores the mediation effect of social networks with these two dimensions on Internet use and organic fertilizer application behavior. Results concerning the mediation effects are shown in Table 6. The study examines the mediation effect stepwise according to the mediating effect model. We first test the effect of Internet use on organic fertilizer application behavior with Equation (3) (Regression 1). Then the study explores the impact of Internet use on strong social network ties (Regression 2) and weak network ties (Regression 3), respectively, with Equation (4). Finally, the research analyzes the effect of Internet use and two dimensions of social networks (strong and weak ties) on organic fertilizer application behavior with Equation (5) (Regression 4 and Regression 5). Column 2 indicates that the Internet significantly influences farmers' organic fertilizer application behavior at the 5% significance level. While the results in column 3 and column 4 illustrate that the Internet effect on strong and weak social network ties is significant at a 1% level. Column 5 and Column 6 demonstrate that the effects of the Internet and the two dimensions of social networks (strong ties and weak ties) on organic fertilizer behavior are substantial at 5%, 1%, and 10%, 5% significance levels, respectively. The results above suggest that the strong and weak ties of social networks play a partial mediating role in Internet use's influence on organic fertilizer application behavior. Thus, the hypotheses H2, H2-1, and H2-2 are all endorsed.

Table 6. Mediation role of social networks.

	Regression 1	Regression 2	Regression 3	Regression 4	Regression 5
Variables	Organic Fertilizer Application	Strong Ties	Weak Ties	Organic Fertilizer Application	Organic Fertilizer Application
Internet Use	0.2827 ** (0.1110)	0.4005 *** (0.0861)	0.6153 *** (0.0878)	0.2285 ** (0.1127)	0.2079 * (0.1152)
Strong Ties	-	-	-	0.1447 *** (0.0482)	-
Weak Ties	-	-	-	-	0.0905 ** (0.0358)
Control Variables	Yes	Yes	Yes	Yes	Yes
LR chi2 (n)	99.09	44.37	207.75	108.21	105.55
Pseudo R^2	0.1023	0.0208	0.0847	0.1117	0.1090
Log-likelihood	−434.6596	−1043.9282	−1122.839	−430.09676	−431.43024
Prob > chi2	0.0000	0.0000	0.0000	0.0000	0.0000

Note: The significance level at 1%, 5%, 10% are represented by asterisk ***, **, *, respectively. Standard errors are reported in parentheses.

The strong network ties mainly consist of geography and kinship relationships. Farmers can access highly relevant guidance, knowledge, and support from neighbors [76,99]. According to previous research literature [84], farmers have greater trust in strong social network ties, which incorporate the emotional factor into their relationships. On the one side, this kind of social network helps farmers in taking risks of adopting new technology and provides farmers with financial support to alleviate the economic pressure in the production process [72,106]. On the other side, the diffusion of new technology largely depends on imitating each other in a village [107]. Due to the high level of trust in members of strong network ties, farmers are more willing to imitate their behaviors. Therefore, strong network ties influence farmers' organic fertilizer application behavior significantly. The weak network ties in Chinese rural areas mainly indicate a kind of strange relationship, sometimes farmers in this kind of social network have many heterogeneous characteristics such as different growth and working environment [108], therefore, this kind of social network can provide heterogeneous information sources, such as the latest new policies and technologies, which can help farmers to update their production concept and promote farmers' adoption of organic fertilizer. In addition, the Internet can help farmers consolidate strong network ties and increase the scale of weak network ties by conveniently contacting each other on many platforms [109]. Therefore, the strong and weak ties of social networks partially mediate the relationship between the Internet and the farmers' organic fertilizer application behavior. The results above are consistent with Weng et al. [110] and Sun et al. [92].

Moreover, in the prevailing literature, some studies also analyzed social networks and classified them based on the degree of intimacy such as Amaia et al. [76], Melissa Parks [111], and Kamilla et al. [70]. Some studies characterized social networks as network scale, intensity, and mutual trust [72]. However, these studies analyzed the influence of social networks on farmers' behavior, without considering its mediating effect. This aspect makes the current study different from the previous research.

6. Conclusions and Policy Implications

With the rapid development of the Internet in rural areas, its influence on farmers' production cannot be neglected. Furthermore, exploring a practical path to motivate farmers to replace chemical fertilizer with organic fertilizer and address climate change is essential. To explore the phenomenon empirically, the study gathered data from 797 vegetable farmers from Shouguang City, Shandong Province of China, given that the area has the largest vegetable wholesale market in China. Moreover, the study employed the propensity score matching (PSM) method to examine the direct influence of Internet use on farmers' organic fertilizer application behavior and found that the Internet plays a significant role in switching farmers' behavior towards the adoption of organic fertilizer from chemical fertilizers. The study also employed heterogeneous analysis based on different groups of farmers. It revealed that Internet use positively impacts the group of farmers with higher education levels, lower vegetable farming income, and more vegetable planting laborers. Furthermore, mediation effect analysis unveiled that both strong and weak social network ties play a mediating role in the impacts of the Internet on farmers' organic application behavior.

Based on the findings, the current study proposes that the government should make a policy to encourage farmers to reduce their reliance on chemical fertilizer and substitute chemical fertilizer with organic fertilizer. In this regard, the government should first emphasize establishing the Internet infrastructure to increase the Internet access rate in rural areas. Additionally, an official Internet information service platform should also be built, and training ought to be provided for farmers to help them better search for agricultural information on the Internet. Second, results concerning the heterogeneous effect of the Internet's influence on farmers' behavior indicate that the government should mainly provide training for farmers with a higher education level, lower vegetable farming income, and more vegetable planting laborers and encourage these kinds of farmers to convey their knowledge and information to other farmers. Third, in the context of the social network, the study proposes that the government should incentivize farmers to share and obtain current agricultural technology information through the official Internet platform by carrying out many kinds of activities and measures such as creating Internet forums and subsidy distribution to consolidate farmers' strong network ties and expand their scale of weak ties. Finally, the government should combine online tools and offline production experience sharing among social network fellows to improve farmers' technology application ability, especially the skill of applying organic fertilizer.

7. Limitations

The study also has some limitations in the following aspects. Firstly, this study only employs binary variables to describe farmers' organic fertilizer adoption behavior, the impact of Internet use on the degree of farmers' organic fertilizer application is not considered due to data accessibility. Secondly, the heterogeneity analysis can include many other characteristics such as farmers' age, training, etc. In conclusion, these limitations set avenues for in-depth future analysis.

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