Can Internet Use Improve Farmers' Welfare Effect ——A Case Study of Chinese Vegetable Growers

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Abstract: This article uses the data of 797 vegetable growers in Shouguang, Shandong Province, and the endogenous conversion model to investigate the impact of Internet use on household welfare. We select the per-mu vegetable yield, net income, and per capita net income of households as welfare indicators. The results show: ① Internet use can significantly improve the farmers' welfare effect. ②Under counterfactual assumptions, when farmers who use the Internet do not use it, the farmers' vegetable yield per mu, net income and household per capita net income will drop by 10.88%, 13.96% and 9.46%. When farmers who do not use the Internet use it, the farmers' vegetable output, net income and family per capita net income will rise by 13.62%, 16.66% and 11.64%. Internet use has the most excellent effect on the net income of vegetables, followed by the yield per mu, and the net income per household is the lowest. ③ Compared with small-scale farmers, Internet use has a better impact on the welfare of large-scale farmers, which also widens the welfare gap between farmers to a certain extent. Based on this, make suggestions to strengthen information infrastructure, improve information technology training, and adjust support policies promptly.

Keywords: Internet use; yield per mu; net income; per capita net income of households; Farmers' welfare effect

Introduction

The national nature of socialism with Chinese characteristics needs to guarantee farmers' welfare to achieve social harmony and stability and long-term stability. The welfare effect is an important indicator to measure economic development, social progress and people's living standards.

Therefore, exploring the driving factors of the improvement of farmers' welfare effect has important practical significance for improving farmers' quality of life and improving farmers' economic status. At present, agricultural informatization is a vital engine driving rural economic development（Yunis, et al.,2018）. Existing literature has carried out detailed research on the relationship between informatization and social production and found that information technology not only affects economic output and farmer welfare, but also plays a crucial role in the national development process (Fairlie,2006; Gentzkow et al.,2011). Nowadays, as the "high speed of information," the Internet has developed rapidly in rural areas and has become an essential modern communication tool for farmers and a driving force for economic growth. The No. 1 Central Document in 2020 clearly stated: Accelerate the application of information technologies such as the Internet of Things, big data, blockchain, artificial intelligence, and fifth-generation mobile communication networks in the agricultural field. Governments at all levels have invested great enthusiasm to promote the construction of agricultural informatization. The national ministries and commissions have also successively built and implemented "Internet +" demonstration projects. Intelligent digital platforms, big data cloud services, e-commerce skills training, etc., making unremitting efforts to promote the development of the agricultural economy and the improvement of welfare levels for the use of the Internet. As of June 2020, the number of rural Internet users in my country has increased to 285 million, accounting for 30.4% of the total Internet users. The Internet penetration rate in rural areas reached 52.3%, and the difference in Internet penetration rates between urban and rural areas narrowed by 6.3 percentage points.

This article discusses the economic effects of Internet use from the perspective of farmers' welfare and tries to answer: Can Internet use improve farmers' welfare? Does Internet use expand or narrow the gap in welfare among farmers? An in-depth analysis of the impact of Internet use on farmers' welfare is conducive to exploring the "hematopoietic" mechanism of Internet use and provides useful explorations for rural informatization, modernization, and farmers' changes welfare.

At present, there are many controversies about whether the impact of Internet use on the welfare of farmers is "information welfare" or "information gap," and there is still no consensus among the theoretical circles. Some scholars believe that Internet users can obtain and share the latest knowledge and information (Guo et al.2017) and improve farmers' economic status and market competitiveness (Dimaggio & Bonikowski,2008). The information economics argument also believes that the Internet's information can reduce individual information search costs, thereby profoundly affecting its economic development, technological progress, and production efficiency(Stigler,1961). That is, Internet use has "information benefits." However, some scholars have found that while the use of the Internet improves farmers' production efficiency and economic development, it may also produce inequality in human society (Tan et al.,2017). Because people with different income levels or education levels have large differences in the degree of acceptance and use of the Internet, which leads to large differences in the economic benefits of recipients and exclusions, thus widening the gap between the rich and the poor(Heinz,2002). That is, the "information gap" formed by the use of the Internet. Based on the above analysis, although scholars have conducted a lot of empirical analysis and theoretical discussion on the economic effects of Internet use on farmers, there are still problems that need to be studied in depth. It mainly includes: First, whether the impact of Internet use on farmers' welfare increases or decreases has not yet reached a consistent conclusion. Second, most studies did not include Internet use in the entire link of agricultural production, nor did they explore the economic effects of Internet use from the perspective of farmers' welfare. Third, most existing studies use the instrumental variable method and propensity score matching method to test the impact of Internet use on agricultural production. The former ignores the heterogeneity of the treatment effect, while the latter does not consider its endogeneity, both of which may cause deviations in the estimated results.

Given this, the article uses the per-mu vegetable yield, net income, and household income indicators as household welfare indicators. Based on a sample of 797 vegetable growers in Shouguang, Shandong Province, the endogenous conversion model was used to analyze the impact of Internet use on farmers' welfare and the differences in the welfare effects of farmers of different sizes. Compared with the previous literature, the article incorporates the Internet's use into the overall analysis framework of vegetable production, price and income. It pays attention to the changes in its welfare from the production link to the sales link and supplements the previous use of a single indicator to measure farmers' welfare. To ensure the article's accuracy and stability, it chooses the endogenous transformation model (ESR) to solve sample endogeneity and uses the seemingly uncorrelated regression model to conduct robustness tests.

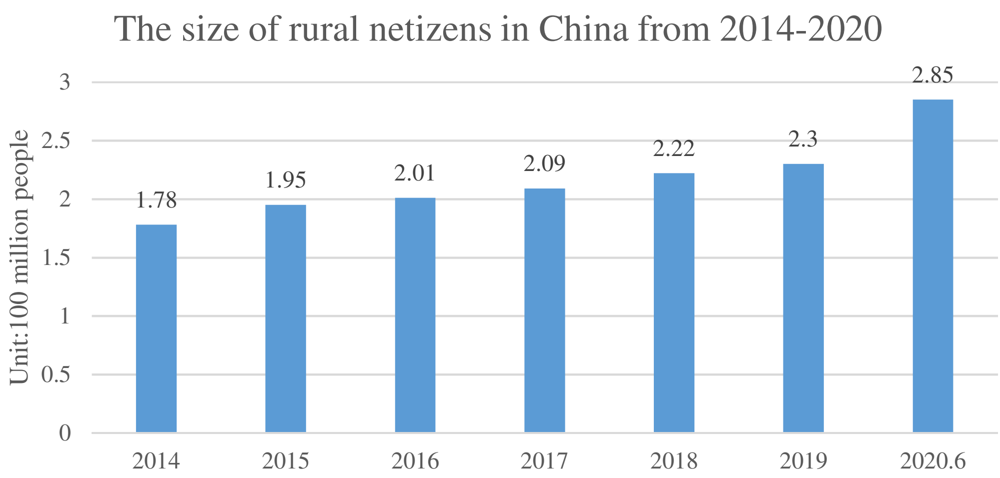

Table 1 The scale of Chinese rural netizens from 2014 to 2020

1 Theoretical analysis and model setting

1.1 Farmer welfare effect

Welfare is the degree of satisfaction that an individual consumes goods or services. However, because the "degree of satisfaction" is difficult to measure, individual welfare is usually expressed by economic practice. The higher the economic level, the better the personal welfare status. Farmers are rational economic people whose ultimate goal is to maximize profits. Therefore, this article selects economic welfare as its research object. The theory of social practice believes that: livelihood capital is the sum of resources and abilities owned by an individual or family, and it is also the basis for affecting individual practical activities and business performance（Bourdieu,1986）. The most common livelihood capital of farmers has five categories: human capital, natural capital, physical capital, financial capital and social capital. Human capital contains individual physical strength, knowledge and skills. Improving human capital is a crucial way to increase learning ability, knowledge accumulation and innovation awareness (Fleisher,2010). Natural capital (such as land) is the fundamental guarantee for rural social stability and farmers' survival. Material capital is a condition for farmers to maintain good initiative and strong resistance to market competition pressure. Simultaneously, physical capital is also an indirect force that widens the gap in farmers' economic strength (Wan&Zhou,2005). The allocation of financial capital contributes to the increase of family property income, and the return from this investment can increase individual happiness and satisfaction (Merkle et al.,2015). Social capital is a permanent collection of social network resources based on the same cognition (Bourdieu,1986), which can provide individuals with instrumental and emotional support(Lin,2001).

In addition to the traditional livelihood capital, farmers' welfare is also affected by the prices of agricultural products（Mellor,1978）, agricultural social services（Friis-Hansen & Duveskog, 2012；Houssou et al., 2013）, and government subsidies(Gorter&Fisher,1993). In previous studies, there is little mention of the impact of rural infrastructure construction, such as Internet use, on farmers' welfare.

1.2 Internet use and farmers' welfare effects

Farmer's welfare is an important indicator that reflects the living conditions and living standards of farmer households and an important standard for measuring my country's modernization progress (Li et al.,2015). As a communication technology that promotes informatization, Internet use runs through the entire agricultural industry chain and serves the whole production process. A comprehensive grasp of the changes in the use of the Internet on farmers' welfare analyzes the whole process from the most basic cost input to the output and income of agricultural products and then to farmers' income. Therefore, this article uses per-mu yield, net income, and household net income per capita as indicators to explore the impact of Internet use on farmers' welfare.

Internet use provides farmers with comprehensive agricultural information services. Simultaneously, the Internet user's accuracy and convenience can also reduce the procedures and costs of obtaining information, allowing farmers to make optimal production decisions (Fafchamps&Minten,2012). The accurate market information brought by Internet use can reduce agricultural transaction costs, stimulate agricultural production and increase agricultural income (Aker,2014). Mainly manifested in the following aspects: (1) The use of the Internet helps improve the ability to collect and use information so that the supply of agricultural products can effectively connect the demand to guide production better and increase output (Baorakis,2002). The Internet provides accurate, dynamic and scientific all-around information services for agricultural production and management. The intelligent management and precise services it brings to agricultural production effectively increase agricultural products' output (Garrett,2013). From a long-term perspective, using the Internet can change the agricultural planting structure and introduce new varieties, thereby increasing agricultural productivity (Nakasone,2014). (2) The Internet use can also solve information asymmetry, optimize the allocation of traditional production factors such as land, capital, and labor, thereby changing the current "high input, high consumption, and high pollution" economic development mode. It can reduce excessive dependence on resource consumption in agricultural modernization (Varian et al.,2004; Sun&Li,2018). Also, the use of the Internet has a significant positive effect on increasing the sales of agricultural products in the market, increasing the sales prices of agricultural products, and improving the welfare of farmers （Jensen,2007; Burga & Barreto,2014; Shimamoto et al.,2015）. (3) Internet use enables farmers to obtain more information about agricultural inputs and change their investment strategies to grow more profitable crops, positively impacting increasing income. Internet use can also liberate farmers from heavy physical labor and engage in non-agricultural industries with higher income (Fernanado, 2012). At the same time, the information brought by the Internet can reduce the waiting time of non-agricultural employees, improve their skills, and increase employment opportunities for farmers (Fountain,2005; Zhou&Li,2017; Lu et al.,2016). In addition, the integration capabilities, flexibility and productivity advantages of the Internet can also provide farmers with more entrepreneurial opportunities (Kim& Orazem,2017; Reuber& Fischer,2011; Cumming,2010).

However, some researchers believe that Internet use has a significant negative impact on welfare effects. The Internet use creates a "digital gap" between the information-rich and the information-poor, leading to an increase in the income gap between individuals(Bonfadelli,2002；Wouterlood,2012). The development of the Internet will only benefit those wealthy people. The wealth accumulation of the rich will continue to be higher than that of the low-income people, leading to a growing gap between the rich and the poor (Britz et al.,2001; Clark et al.,2002; Martin,2003). Graham & Nikolova (2013) believe that the use of the Internet makes mobile payment very convenient, which leads to the continuous increase of individual expenditure. Besides, Internet use may also lead to Internet addiction users, addicted to the virtual world, lower social trust between reality, which have a significant negative impact on the welfare effects(Abatini,2017).

1.3 Model setting

Assuming that the net income obtained by farmers using the Internet isD_{ia}^*, the net income obtained by not using the Internet is D_{in}^*, and the difference between the two (the difference between the net income of users and non-users) is D_i^*. When D_i^*>0, farmers who use the Internet have higher net income than non-users, and farmers choose to use the Internet. But $D_i^*$is a latent variable and cannot be directly observed, so it is expressed as a function composed of observable variables, such as the following latent variable model:

$$A_i = \begin{pmatrix} 1, & A_i^*>0 \\ 0, & A_i^*\leq 0 \end{pmatrix} \quad (1)$$

In the formula (1), $A_i$represents the behavioral decision of whether to use the Internet, $A_i = 1$ represents that the farmer uses the Internet, and $A_i = 0$ represents that the farmer does not use the Internet. Construct the impact of farmers' use of the Internet on farmers' welfare:

$$Y_i = \beta' X_i + \gamma' A_i + \varepsilon_i \quad (2)$$

In the formula (2), Y_i represents the welfare effect of farmers, $X_i$is the external environmental characteristic variables such as personal characteristics, family characteristics, and village characteristics that affect the use of the Internet by farmers. $\beta'$and γ' are the coefficients to be estimated, and ε_i is the random interference term.

The article uses the endogenous transformation model (ESR) proposed by Maddala (1983). The endogenous transformation model (ESR) is Heckman's extended model. It is a selection bias correction method that relaxes the restriction that all common influencing factors must be included in the equation and can effectively improve the estimation results' invalidity and bias. Simultaneously, it also makes up for the propensity score matching method (PSM) to solve observable variables' heterogeneity (Ma and Abdulai, 2016). The article uses an endogenous transformation model to link farmers' behavior using the Internet with the equation of farmers' welfare effects. Based on considering the sample selection bias caused by the heterogeneity of observable and unobservable factors, it also estimates the element usage and welfare effects of farmers' Internet use behavior.

The endogenous transformation model includes two stages: the selection model and result model:

Step 1: The selection equation of whether to use the Internet:

$$A_i = \delta' Z_i + \mu_i \quad (3)$$

Step 2: The welfare level equation of farmers who use and not use the Internet:

When $A_i = 1$,

$$Y_{Ti} = \beta_T X_{Ti}' + \varepsilon_{Ti} \quad (3a)$$

When $A_i = 0$,

$$Y_{Ui} = \beta_U X_{Ui}' + \varepsilon_{Ui} \quad (3b)$$

In the above formula, A_i represents the binary variable of whether the farmer chooses to use the Internet, Z_i is the variable that affects the farmer's choice to use the Internet, μ_i、ε_{Ti} and ε_{Ui} are error terms.Y_{Ti} and Y_{Ui} represent the welfare effects of farmers who use the Internet and those who do not use the Internet, respectively.

Although the endogenous transformation model (ESR) allows the explanatory variables of the behavior equation and the explanatory variable of the result equation to overlap, to identify the endogenous transformation model better, at least one of the explanatory variables of the result equation is different from the behavior equation. The article incorporates whether the village has information technology training as an instrumental variable in the Internet use behavior decision. The reason for choosing this type of instrumental variable is that whether the village has information technology training will affect the use of the Internet by farmers but will not affect the average vegetable output per mu of farmers. To test this instrumental variable's effectiveness, we made a Probit model on the behavior selection equation and an OLS regression on the result equation. The results found that this instrumental variable is significant in the selection equation but not in the result equation. Further analysis found that the selected instrumental variable is not related to net income and household net income per capita, indicating that the instrumental variable is effective.

At the same time, the inverse Mills λ_T、λ_U and the covariance σ_T、σ_U calculated based on the farmer's behavior equation are multiplied into the influence effect equation to obtain:

When $A_i = 1$,

$$Y_{Ti} = \beta_T X'_{Ti} + \sigma_{Tu}\lambda_{Ti} + \varepsilon_{Ti} \quad (4a)$$

When $A_i = 0$,

$$Y_{Ui} = \beta_U X'_{Ui} + \sigma_{Uu}\lambda_{Ui} + \varepsilon_{Ui} \quad (4b)$$

Among them, λ_T and λ_U represent the selection bias caused by unobservable factors, and σ_{Tu}、σ_{Uu} represent the covariance of the error term of the selection equation and the result equation. If the covariance is significant, it means that farmers' use of the Internet impacts their welfare, and selective correction is necessary.

1.4 Evaluation of the welfare effects of Internet use

Use the ESR model to construct a counterfactual framework, and compare the average welfare effects of using and not using the Internet. Finally, estimate the average treatment effect of the impact of Internet use on the welfare of farmers Welfare expectations of farmers using the Internet:

$$E[Y_{Ti}/D_i = 1] = \beta_T X_{Ti}^{'} + \sigma_{Tu}\lambda_{Ti} \quad (5a)$$

Welfare expectations of farmers who do not use the Internet:

$$E[Y_{Ui}/D_i = 0] = \beta_U X_{Ui}^{'} + \sigma_{Uu}\lambda_{Ui} \quad (5b)$$

Welfare expectations of use group of farmers when they are not using the Internet:

$$E[Y_{Ui}/D_i = 1] = \beta_U X_{Ti}^{'} + \sigma_{Uu}\lambda_{Ti} \quad (5c)$$

Welfare expectations of non-use group farmers when using the Internet:

$$E[Y_{Ti}/D_i = 0] = \beta_T X_{Ui}^{'} + \sigma_{Tu}\lambda_{Ui} \quad (5d)$$

The average treatment effect of the welfare level of farmers who have used the Internet, that is, the average treatment effect (ATT) of the treated group is expressed as the difference between 5a and 5c:

$$ATT = E[Y_{Ti}/D_i = 1] - E[Y_{Ui}/D_i = 1] \quad (6)$$

Similarly, the average treatment effect of the welfare level of farmers who have not used the Internet, that is, the average treatment effect on the untreated (ATU) of the control group, is expressed as the difference between 5d and 5b:

$$ATU = E[Y_{Ti}/D_i = 0] - E[Y_{Ui}/D_i = 0] \quad (7)$$

2 Data source and variable description

2.1 Data source

The research data mainly comes from the field survey conducted by the research team in Shouguang City, Shandong Province, in September 2019. The survey adopted a combination of stratified sampling and random sampling. Specific sampling steps: randomly select 7-9 sample townships in the sample area, randomly select 6-8 sample villages in each sample township, and randomly select 10-15 farmers in each sample village to conduct one-to-one questionnaire interviews. We collected 802 questionnaires, deleted invalid questionnaires, and obtained 797 valid questionnaires, accounting for 99% of the total sample. The survey content includes the characteristics of individuals, families, villages. Personal surveys include the respondents' basic characteristics, income status, Internet usage, etc.; household surveys include family demographic characteristics, income and expenditure status, family environment, and property. The contents of the village survey mainly include traffic conditions and information training.

2.2 Variable description

Internet use refers to using the latest information technology to make information exchange between people more rapid and accurate and continuously promote information technology's rapid development (Yan,2010). This article uses mobile phones and computers as Internet representatives. However, rural households in Shouguang, Shandong, have a high adoption rate of mobile communication, and most people use it for entertainment and communication. Therefore, to measure the impact of Internet use on agricultural production, this paper selects whether to actively use mobile phones and computers to query agricultural information as an indicator (Sheng et al.,2017). 394 farmers in the sample use the Internet to actively inquire agricultural information, accounting for 49.44% of the total sample.

Farmer's welfare reflects farmers' subjective feelings of happiness and social participation and reflects the agricultural economy's development. It is a collection of economic welfare and non-economic welfare, and the utility of farmer economic welfare is the most direct goal and pursuit (Zhang&Yang,2019). It is generally measured by the annual living expenses, the per capita net income level of the family, the incidence of poverty, the annual output of agricultural products and the level of net income. However, because high transaction costs and information asymmetry severely restrict local agriculture, farmers engaged in vegetable production and sales face mismatched production and sales and low returns. Therefore, three indicators of vegetable output, net income, and household net income per capita are selected to measure farmers' welfare effect. Among them, the vegetable yield is the average yield of vegetables per mu. The average yield per mu of the total sample is 10277.985kg, with 257 households higher than this value and 540 households lower than this value. Vegetable net income refers to the difference between the output value of vegetables per mu minus input costs. Inputs mainly include the cost of materials such as pesticides, fertilizers, mulching films, and irrigation. The total sample's average net income is ¥10802.43, with 317 households higher than this value and 480 households lower than this value. Family net income per capita refers to the quotient obtained by dividing the annual net income of family members by the sum of all family members. The average value of 797 samples is ¥41377.09, with 489 households above this value and 308 households below this value.

Judging from household heads' characteristics in Table 1, the younger the age, the more educated farmers are more likely to use the Internet. In terms of family characteristics, the more muscular the rural households' economic strength, the higher the degree of specialized production, the more government subsidies, and the more active they are to participate in rural professional cooperatives, the more likely they are to use the Internet. The amount of financial loans of the user group is much higher than that of the non-use group, indicating that the former may have a higher degree of risk appetite. From the input perspective, the material input, labor input, and land input of the non-use group are higher than those of the user group. In contrast, the mechanical input and technical input are the opposite. From the perspective of village characteristics, farmers who are far away from the trading market and have received information technology training are more inclined to use the Internet (see Table 1).

Table 1 Variable setting and description

Variable category	Variable name	Variable description and unit	Use Group N=394	Non-use group N=403
Household characteristics	age	Age of household head (years)	49.631	53.852
	Age squared	Square of the age of household head	2512.765	3008.311
	Years of education	Education years of household head (years)	8.673	7.798
Family characteristics	Annual vegetable income	Annual total income of farmers from growing vegetables (yuan)	133350.141	102646.152
	The proportion of non-agricultural income	The non-agricultural income of rural households as a percentage of total income（%）	0.211	0.264
	Annual vegetable expenditure	The total expenditure of farmers on growing vegetables (yuan)	23736.642	26763.694
	Total number of households	The total population of rural households (persons)	4.693	4.422
	Vegetable planting years	Years of household head engaged in vegetable production (years)	25.611	29.180
	Vegetable yield	Vegetable yield per mu (kg)	22130.801	18981.142
	Financial loan	Number of rural household loans (yuan)	6317.262	2841.193
	Government subsidies	Government agricultural subsidy	97.970	85.02

		(yuan)		
	Whether to join a rural cooperative	Join=1, not join=0	0.141	0.062
Production input	Material data input	The cost of purchasing pesticides, fertilizers, seeds, hired workers, etc. (yuan)	5119.262	6026.923
	Land input	Vegetable cultivation area (mu)	3.501	4.424
	Labor input	Labor input per mu (work)	2.682	2.953
	Technology investment	Quantity of vegetable production technology adopted (item)	2.844	2.633
	Mechanical investment	The value of farmers buying agricultural machinery (yuan)	3869.321	3246.074
Village characteristics	Distance to the sales market	Distance from village to sales market (km)	4.121	2.785
	Is there information technology training	Yes=1, No=0	0.480	0.312

Note: Shouguang mainly grows solanaceous vegetables, such as tomatoes, cucumbers, eggplants, sweet peppers, loofah, carrots, etc. Most of the vegetables can be planted twice a year.

3 Empirical result analysis

The Internet use decision-making results and the impact of Internet use on the three welfare indicators are shown in Table 2 to Table 5. The endogenous transformation model can simultaneously estimate the selection equation and the result equation. The selection equation's estimation results are in the second column of Table 2 to Table 5, and the resulting equation is in the third and fourth columns of Table 2 to Table 5.

Table 2 Model estimation results of vegetable yield per mu and Internet usage behavior

Variable	Internet use behavior of farmers	Vegetable yield	
		Use group	Non-use group
age	0.016（0.038）	0.007（0.027）	-0.002（0.029）
Age squared	-0.005（0.004）	-0.001（0.002）	0.009（0.006）
Years of education	0.032（0.021）	0.005（0.016）	-0.020（0.015）

Annual vegetable income	0.096（0.122）	-0.881***（0.155）	-0.796***（0.163）
Vegetable planting years	0.032***（0.006）	-0.005（0.004）	-0.004（0.004）
Government subsidies	0.002（0.002）	0.017（0.038）	0.003（0.002）
Financial loan	-0.004（0.023）	0.019（0.014）	0.006（0.021）
Whether to join a rural cooperative	0.006***（0.002）	-0.001（0.001）	0.003（0.002）
Material data input	-0.027（0.018）	0.042**（0.017）	0.067***（0.025）
Land input	-0.008（0.011）	0.037***（0.007）	0.052***（0.009）
Labor input	-0.072（0.051）	0.076*（0.043）	0.101**（0.042）
Technology investment	-0.043（0.035）	-0.004（0.011）	0.009（0.011）
Mechanical investment	0.095***（0.030）	0.056**（0.028）	0.022（0.027）
Distance to sales market	0.210（0.142）	-0.064（0.065）	0.062（0.089）
Information Technology Training	0.411***（0.101）		
Constant term	-3.332***（1.118）	9.247***（0.752）	7.875***（0.893）
$Ln\ \sigma_T$		-0.369***（0.047）	
ρ_T		-0.396***（0.042）	
$Ln\ \sigma_U$			-0.285***（0.038）
ρ_U			-0.393**（0.027）
LR	7.51***		
Log-likelihood	-12510126		
Obs	796	394	402

Note: ***, **, * indicate that the estimated results are significant at the statistical levels of 1%, 5%, and 10%, respectively. The standard errors are in parentheses, and the same applies below.

Table 3 Model estimation results of net vegetable income and Internet usage behavior

Variable	Internet use behavior of farmers	Net income	
		Use group	Non-use group
Age	0.012（0.038）	0.027（0.043）	-0.029（0.047）
Age squared	-0.005（0.003）	-0.002（0.004）	0.003（0.004）
Years of education	0.029（0.021）	0.023（0.025）	0.003（0.024）

Proportion of non-agricultural income	0.248（0.221）	-0.372***（0.026）	-0.762***（0.266）
Vegetable planting years	0.034***（0.006）	0.013*（0.008）	-0.008（0.007）
Government subsidies	0.001（0.005）	0.042（0.062）	-0.003（0.002）
Financial loan	-0.003（0.023）	0.048**（0.021）	0.024（0.034）
Whether to join a rural cooperative	0.016***（0.006）	0.008（0.014）	0.002（0.004）
Material data input	-0.009（0.016）	-0.084***（0.018）	-0.058***（0.021）
Land input	0.007（0.012）	0.024**（0.011）	0.038**（0.015）
Labor input	-0.108*（0.061）	0.133*（0.074）	0.173**（0.073）
Technology investment	0.014（0.015）	0.031*（0.017）	0.032*（0.018）
Mechanical investment	0.083**（0.039）	0.019（0.046）	-0.026（0.045）
Distance to sales market	0.161**（0.065）	-0.042（0.103）	-0.059（0.146）
Information Technology Training	0.399***（0.094）		
Constant term	-3.145***（1.095）		
$Ln\ \sigma_T$		0.132***（0.050）	
ρ_T		-0.501***（0.181）	
$Ln\ \sigma_U$			0.227***（0.036）
ρ_U			-0.203***（0.078）
LR	9.06***		
Log-likelihood	-1647.885		
Obs	796	394	402

Table 4 Model estimation results of household net income per capita and Internet use behavior

Variable	Internet use behavior of farmers	Net income per capita	
		Use group	Non-use group
Age	0.013（0.039）	-0.19（0.012）	0.008（0.012）
Age squared	-0.005（0.003）	0.003（0.004）	-0.007（0.003）)
Years of education	0.030（0.021）	0.011*（0.007）	0.004（0.006）
Proportion of non-agricultural income	0.043（0.031）	0.038*（0.022）	0.057（0.061）

Vegetable planting years	0.031***（0.006）	-0.007***（0.002）	-0.001（0.002）
Government subsidies	0.002（0.001）	0.016（0.062）	0.006***（0.002）
Financial loan	-0.017（0.009）	0.003（0.004）	0.002（0.001）
Whether to join a rural cooperative	0.006***（0.002）	-0.005（0.004）	0.002**（0.001）
Material data input	-0.004（0.016）	0.059（0.042）	0.018**（0.008）
Land input	-0.008（0.013）	0.030***（0.003）	0.025***（0.004）
Labor input	0.071（0.056）	0.012（0.021）	0.069***（0.017）
Technology investment	-0.015（0.010）	0.006（0.011）	0.009（0.012）
Mechanical investment	0.089**（0.039）	0.022*（0.013）	-0.005（0.011）
Distance to sales market	0.214***（0.105）	0.040（0.029）	0.011（0.035）
Information Technology Training	0.389***（0.102）		
Constant term	-3.262***（1.096）	9.013***（0.422）	7.491***（0.432）
$Ln\ \sigma_T$		-1.153***（0.047）	
ρ_T		-0.411***（0.196）	
$Ln\ \sigma_U$			-1.189***（0.043）
ρ_U			-0.356***（0.169）
LR	8.61***		
Log-likelihood	-1102.709		
Obs	796	394	402

3.1 Analysis of the selection equation of Internet usage decision

It can be seen from Tables 2-4 that the four variables of vegetable planting years, mechanical input, whether to join a rural cooperative, and whether there is information technology training have a significant positive impact on the decision to use modern communication technology. (1) Farmers with longer planting years have accumulated richer planting experience, and rich planting experience can enhance the farmers' ability to learn and use new technologies. (2) Farmers with a high degree of mechanization are more capable of accepting new things and are more likely to use modern communication technology. (3) Agricultural cooperatives can provide a series of assistance such as market information, technical guidance, and financial support to participating farmers. Farmers gradually increase their awareness of new technologies and knowledge in the continuous learning process. (4) Farmers who have received more information technology training better understand the agricultural market environment and information. They can more clearly recognize the inevitability of agricultural informatization and socialization in the future and are more capable of accepting new things like Internet use.

3.2 The result equation analysis of the effect of Internet use on welfare

3.2.1 The impact of internet usage on vegetable yield per mu

From the third and fourth columns of Table 2, there is a significant positive correlation between land input, material data input, labor input and yield per mu. Experience shows that: farmer's factor input is the most effective and direct measure to increase agricultural production and income. Although the marginal income will continue to decrease with the increase of factor input, it still has a significant role in improving farmers' output in the short term. The larger the land for vegetable cultivation, the more likely it is to enjoy the intensive advantages of agricultural specialization, mechanization, and labor division, positively impacting agricultural output. Also, there is a significant negative correlation between the proportion of non-agricultural income and vegetable production. The higher the non-agricultural income of farmers, the lower their emphasis on agricultural production, and the less willing to invest more time and financial resources in agricultural production. It is worth noting that machinery input is positively correlated with farmers in the user group but not related to farmers in the non-use group. It shows that compared with non-use group farmers, using group farmers' mechanization impacts farmers' vegetable output.

3.2.2 The impact of internet usage on net vegetable income

From the third and fourth columns of Table 3, it can be obtained that the proportion of non-agricultural income, material input and net vegetable income have a significant negative correlation. It shows that the larger the proportion of farmers' non-agricultural income, the more material input, the lower the net income of vegetables. Higher non-agricultural income represents an increase in farmers' non-agricultural employment, which intensifies the transfer of high-quality labor from agriculture to non-agricultural industries. It leads to weaker and weaker enthusiasm for vegetable production and negatively affects net income. The more material input, the higher the production cost and the lower the net income. Land input, labor input, and technology input significantly correlate with farmers' net income. The increase in vegetable planting area will obtain the benefits of large-scale operation and obtain more agricultural subsidies. The more labor input, the more likely it is to realize intensive land cultivation and obtain more benefits. The investment in agricultural technology can optimize agricultural products' quality, liberate labor productivity, increase agricultural productivity, etc. Also, vegetable cultivation's length has a significant positive correlation with farmers' net income in the user group. In contrast, the impact on farmers in the non-use group is not significant. It may be because the farmers can get more agricultural information by using the group. The longer the vegetable planting period, the stronger the use group farmers' ability to use various information. The easier it is to increase the farmers' income.

3.2.3 Impact of Internet use on per capita net income of rural households

From the third and fourth columns of Table 4. For the use group of farmers, the household's per capita net income has a significant positive correlation with the length of education, the proportion of non-agricultural income, land input, and machinery input, while a significant negative correlation with the length of vegetable cultivation. Therefore, use group farmers mainly rely on expanding the planting area, increasing agricultural mechanization to supplement the family income. Internet users can break down "knowledge barriers," increase farmers' opportunities to acquire new technologies and new knowledge and guide them to large-scale and mechanized production. Simultaneously, Internet use reduces the cost of communication between farmers and the outside world, making it easier to obtain market employment information, thereby increasing family income from non-agricultural employment. For the non-use group, land input, government subsidies, whether to join a cooperative, material data input and labor input are positively correlated with household income. The non-use group farmers mainly rely on the traditional "extensive" economic growth method of increasing material input, land, capital and other factors to increase their income.

3.3 Average treatment effect of farm household welfare indicators

Table 5 shows the average treatment effect of farmers' Internet use on the three welfare indicators of vegetable yield per mu, net income and household per capita net income. Specifically: when farmers who use the Internet do not use it, their per-mu yield, net income, and family per capita net income will drop by 10.88%, 13.96% and 9.46%. When farmers who do not use the Internet use it, the per-mu yield, net income, and per-capita net income of households will rise by 13.62%, 16.66% and 11.64%. So Internet use has a significant positive impact on improving the farmers' fare of d the magnitude of the impact in net income, yield per mu, and net income per household.

Table 5 The average treatment effect of using the Internet on farm household welfare indicators

Welfare indicators	Group	Using the Internet	Not using the internet	ATT	ATU
Yield per mu	Use group	10.663（0.021）	9.503（0.047）	1.160*** （0.038）	——
	Unused group	11.032（0.022）	9.710（0.023）	——	1.322*** （0.008）
Net income	Use group	12.135（0.034）	10.441（0.185）	1.694*** （0.187）	——
	Unused group	12.377（0.034）	10.609（0.031）	——	1.768*** （0.015）
Net income per capita	Use group	13.155（0.019）	11.910（0.050）	1.245*** （0.050）	——
	Unused group	13.503（0.022）	12.095（0.021）	——	1.408*** （0.012）

Note: The effect values are all-natural logarithms.

4 Robustness test

Similar uncorrelated regression (SUR) can estimate equations, thereby suppressing the correlation of disturbance terms between multiple equations and improving parameter estimation efficiency. The article introduces SUR and iterative SUR to re-do empirical analysis to test the above results' robustness. In order to avoid collinearity, the multicollinearity test was performed. The test results were: the variance inflation factor (VIF) was less than 2, indicating no multicollinearity issue among the variables. In order to reduce the influence of heteroscedasticity on the data, all dependent variables are processed logarithmically.

SUR regression must satisfy the hypothesis that the equation's disturbance term is related to the same period. Therefore, the three regression equations' disturbance terms need to be tested for "no synchronization correlation": the chi-square value is 454.996, P=0.0000<0.001. Therefore, the null hypothesis that the disturbance terms of each equation are mutually independent can be rejected. The empirical results are shown in Table 6.

Table 6 The impact of Internet use on the welfare of farmers (SUR)

	SUR			SRU_i		
	Yield	Net income	Net income per capita	Yield	Net income	Net income per capita
Whether to use internet	0.214***	0.273***	0.189***	0.214***	0.273***	0.189***
Age	0.009	0.004	-0.005	0.009	0.004	-0.005

Age squared	-0.002	0.001	0.001	-0.002	0.001	0.001
Years of education	-0.017	0.018	0.035***	-0.017	0.018	0.035***
Proportion of non-agricultural income	-0.572***	-0.678***	0.757***	-0.572***	-0.678***	0.757***
Vegetable planting years	0.008	-0.004	-0.035	0.008	-0.004	-0.035
Government subsidies	0.018*	-0.040**	0.013	0.018*	-0.040**	0.013
Financial loan	0.004	0.036*	0.001	0.004	0.036*	0.001
Whether to join a rural cooperative	0.108*	0.157	-0.029	0.108*	0.157	-0.029
Material data input	0.435***	0.520***	0.405***	0.435***	0.520***	0.405***
Land input	0.061***	0.021*	0.017***	0.061***	0.021*	0.017***
Labor input	0.226*	0.284	0.279**	0.226*	0.284	0.279**
Technology investment	0.004	0.025**	0.017***	0.004	0.025**	0.017***
Mechanical investment	0.057**	0.042*	-0.035	0.057**	0.042*	-0.035
Distance to sales market	0.063	-0.056	0.049	0.063	-0.056	0.049
_cons	5.148***	5.278***	7.128***	5.148***	5.278***	7.128***
R-sq	0.335	0.243	0.367	0.335	0.243	0.367

From the empirical results in Table 6, the use of the Internet by rural households has a significant positive correlation with per-mu yield, net income, and household per capita net income. That is, the use of the Internet by farmers can improve the welfare of farmers. In addition, it can be concluded from the coefficient value that the greatest positive impact of the use of the Internet by farmers is the net income of vegetables, followed by the yield per mu, and the least impact on the net income per capita of the household. This conclusion supports the robustness of the above empirical analysis.

5 Analysis of heterogeneity

The article divides the sample farmers into small-scale farmers group (a vegetable area less than 5 acres) and large-scale farmers group (a vegetable area more than 5 acres (inclusive) according to the area of vegetable production land. Calculate the treatment effects of these two groups of farmers' use of the Internet on the per-mu vegetable output, net income, and per capita net income of the family.

Table 7 shows that the treatment effect (ATT) of per-mu vegetable yield, net income, and per capita net income of households using the Internet are 1.093, 1.458, and 1.005 for the small-scale level group, and 1.355, 1.771, and 1.321 for the large-scale level group, respectively. It shows that the Internet's impact on farmers' welfare increases with the expansion of farmland scale. The use of the Internet has expanded the welfare gap between farmers to a certain extent.

Table 7 Differential analysis of the welfare effect of farmers with different scales of farmland

Index	Yield per mu		Net income		Net income per capita	
	ATT	ATU	ATT	ATU	ATT	ATU
Small scale	1.093***（0.327）	1.186***（0.281）	1.458**（0.586）	1.583***（0.453）	1.005***（0.124）	1.183***（0.277）
Large scale	1.355***（0.190）	1.433***（0.176）	1.771***（0.169）	1.904***（0.327）	1.321***（0.138）	1.352***（0.347）

Note: Effect values are all-natural logarithmic values.

6 Conclusion and insights

Based on the theoretical analysis of farmers' Internet use's decision-making mechanism and production process, We select farmers' vegetable yield per mu, net income, and family's per capita net income as indicators to measure farmers' welfare. This article examines the impact of Internet use on farmers' welfare, and the results show that Internet use can significantly improve farmers' welfare effects. Specifically, under the counterfactual hypothesis, if the farmers' actual use group does not use the Internet, the farmers' vegetable output, net income, and family income will fall by 10.88%, 13.96% and 9.46%. If the actual farmers do not use the Internet, the farmers' vegetable output per mu, net income and family per capita net income will increase by 13.62%, 16.66% and 11.64%. That is to say, Internet use has the greatest effect on the increase in net income of vegetables, followed by per mu yield, and the lowest per capita net income of households. Further analysis of the welfare effects of farmers of different sizes can be obtained: Compared with small-scale farmers, Internet use has a better effect on large-scale farmers' welfare. It also widened the welfare gap between farmers to a certain extent.

Based on the above conclusions, we offer the following insights: First, Improve infrastructure construction and improve Internet use. Improve the Internet's coverage and speed to ensure a stable and fast modern communication environment for farmers. Speed up the construction of a network information platform, strive to provide farmers with a mature and reliable planting industry software general system, and then solve information fragmentation and data islands in agriculture. Second，Carry out diversified Internet use knowledge training and guide farmers to use the Internet to improve farmers' welfare. Actively use the government, enterprises, universities and other social organizations to continuously update the training forms and content of Internet use and organically connect with agricultural production. It will reduce production and operation costs, optimize resource allocation, broaden sales channels, and improve farmer welfare. Third, Pay attention to the widening trend of the economic benefit gap caused by using the Internet and adjusting the support policy to the disadvantaged promptly. Small-scale farmers are the critical propaganda and encouragement objects for Internet use to compensate for the group differences in welfare benefits.

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