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The impact of ICT application on farmers' subjective well-being: Based on the mediation effect of absolute income and relative income

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Abstract

Information and communications technology (ICT) plays anhas become significant support for the life of Chinese farmers and the modernization of agriculture. Does the access and application of ICT mediated by smartphones and computers have an impact on farmers' subject well-being (SWB) and what are its underlying mechanisms? Aaccording to the theoretical analysis framework of "ICT→ income (absolute income and relative income)→farmers' SWB", based on the micro-survey data collected from the major apple production areas in China, the Oprobit Model, conditional mixed process method, and the mediation effect model to analyze the impact of ICT application on farmers' subjective well-being and the medication effect of absolute income and relative income. The findings show that, (1) the smart mobile use years, mobile Internet use years, computer use years and fixed broadband Internet use years all improve farmers' SWB. (2) the mobile Internet application intensity, fixed broadband Internet application frequency and fixed broadband Internet application intensity all significantly improve farmers' SWB, but the mobile Internet application frequency has not worked on the whole. (3) the smart mobile use years, mobile Internet use years and fixed broadband Internet use years not only improve farmers' SWB directly but also improve farmers' SWB indirectly by increasing farmer' absolute income and relative income, while the computer use years only improve farmers' SWB indirectly by increasing farmers' absolute income and relative income.

Keywords: ICT Application; Subjective Well-Being; Absolute Income; Relative Income; Mediation Effect

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Introduction

Since the introduction of Internet technology in China in the 1990s, ICT mediated by mobile Internet and fixed broadband Internet has gradually penetrated into rural agriculture. According to the 48th Statistical Report on China's Internet Development released by the China Internet Network Information Center (CNNIC), as of June 2021, the size of rural Internet users was 297 million, accounting for 29.4% of the overall Internet users, and the Internet penetration rate in rural areas was 59.2%. Along with rural informatization, ICT has played an important role in promoting the fairness of public services between urban and rural areas, resolving urban-rural information asymmetry (Zhang 2016; Song 2017), and optimizing urban-rural factor allocation. ICT has become a "powerful tool" for improving the income of rural residents (Liu and Han 2018; Zhou 2016), narrowing the urban-rural income gap, and eliminating the unbalanced and insufficient development of agriculture and rural areas (Gao et al. 2018). Therefore, does ICT application improve farmers' SWB? And how ICT application affect farmers' SWB. To answer the above questions are intended to provide empirical evidence for the formulation of agricultural and rural ICT policies to resolve the contradiction between unbalanced and insufficient agricultural and rural development and farmers' SWB.

Around the topic of the relationship between ICT and SWB, existing empirical studies can be broadly divided into the following main paradigms. First, previous studies focused on the impact of whether use Internet or not on SWB, but did not fully consider the heterogeneity of ICT access and application. Second, the mechanism analysis of ICT affecting SWB mainly concentrated on factors surrounding individuals such as alienation, information resources, social support identity, and social entertainment (Xu et al. 2021; Gan and Wang 2021; Chen and Yang 2021), neglecting to analyze from a comparative perspective. To make up for the gap of the existing researches, this paper took micro data from China's main apple producing areas, and made a careful division of the access and application of ICT based on the existing ones, focusing on the mediation effect by absolute income and relative income in the relationship between ICT and farmers' SWB. Based on the existing literature, the marginal contributions of this paper is considering the impact of ICT application's heterogeneity on farmers' SWB. Additionally, the mediation analysis from the perspective of income may provide empirical arguments to improve farmers' SWB based on eliminating the unbalanced and insufficient development of agriculture and rural areas.

The subsequent parts of this paper are organized as follows: Section 2 constructs a theoretical analysis framework and proposes research hypotheses based on literature related to

ICT and SWB, section 3 introduces the method, section 4 introduces the data, variable selection, and descriptive statistics, section 5 analyzes the effects of ICT application on farmers' SWB, and the medication effect of income (absolute income and relative income) between ICT application and farmers' SWB, and section 6 summarizes the conclusions policy implications.

Analytical framework

The impact of ICT on farmers' SWB

So far, the discussion on the relationship between ICT and SWB has focused on the impact of Internet use on SWB. By combing the existing literatures, researches on the relationship between the Internet and SWB can be divided into two categories. The first category is "supportive" of the relationship between ICT and SWB, holding that the multifunctional nature of the Internet provides rich information resources that help people gain social support and recognition, which in turn improve the residents' SWB (Cilesiz and Ferdig 2003; Huang 2015; Xu et al. 2021). In addition, this view is equally adaptive for special groups such as the elderly and people with autism (Shapira et. Al 2007; Ward 2016). The second category is "against" the relationship between the Internet and SWB, holding that the frequent use of the Internet not only increases people's loneliness, creates negative emotions, and causes social isolation (Kraut et. Al 2015; p énard et al. 2013; Sanders et al 2000), but also can continuously raise expectations of material needs, ultimately leading to a decrease in SWB and life satisfaction (Bruni and Stanca 2006).

In general, the findings of some related studies in China are consistent with the first category, which concluded that Internet use has a positive effect on residents' SWB. Based on comprehensive survey data, Zhu and Leng (2018) systematically analyze the effect of Internet use on residents' SWB, and the results show that Internet use significantly improves residents' SWB, and the rural residents' SWB obtained by using the Internet is significantly stronger than that of urban residents. Leng and Cao (2018) reached a similar conclusion based on data from the Chinese Household Tracking Survey.

In summary, it can be seen that studies on the relationship between ICT and SWB are divergent, while studies in China tend to be consistent, rooted in the fact that the social contexts of domestic and foreign studies are very different. Particularly, the findings of studies in China's rural areas have higher reference significance. Firstly, the loneliness and social isolation caused by excessive Internet use can be significantly reduced or disappear in rural areas of China, which are acquaintance societies with close interactions between neighbors. Secondly, with the

continuous promotion of rural informatization, the productive and living and productive use of ICT with smartphones and computers has brought many benefits to rural residents, directly or indirectly enhancing their SWB. China's rural areas are still in the bonus stage of continuous development of information network business and expansion of coverage area (Xu et al. 2021). Accordingly, we propose the research hypothesis1.

Hypotheses1: ICT application can significantly improve farmers' SWB

Medication effect of ICT application on farmers' SWB by absolute income and relative income

In terms of the impact of ICT on income, existing studies mainly focus on the impact of Internet use on absolute income, and the findings agree that the Internet contributes to the increase of farm household income (Wang et al. 2011; Liu et al. 2015; Liu and Han 2018; Hua 2018; He and Kong 2019). Specifically, the access and application of ICT promote the growth of farmers' income from four aspects: agricultural production income, wage, business, and property income.

For the effect of income on SWB, the relationship between the two has gradually become a hot topic in economics since the proposal of the "Easterlin paradox" in 1974. There have been many controversial studies on the "happiness-income" puzzle, including the absolute income theory (Oshio and Kobayashi 2011), the relative income theory (Wolbring et al. 2013), the income inequality theory (Wang et al. 2015), and the income-consumption theory (Lin et al. 2012).

To begin with, Researches on relative income and happiness can be considered as an explanation of the "happiness-income paradox" from the perspective of relative income, and its theoretical basis is mainly derived from social comparison theory (Wood 1996) or desire theory (Rojas 2007), which suggests that people consider relative position more than absolute position when making judgments (Guan 2010). From the empirical studies of relative income and happiness, the findings show some heterogeneity due to different reference groups. Among them, most scholars measured relative income based on downward comparisons or parallel comparisons and believed that relative income contributed to happiness (Fischer and Torgler 2008; Luo 2009; Guan 2010; Pei 2010; Zhou et al. 2018).

Last but not least, regarding the researches on absolute income and happiness, academics have not yet reached a consensus, totally divided into the following four categories of research findings. First, absolute income has a positive effect on happiness, such as the studies of

Veenhoven (1996), Frey et al. (2002), Xing (2011), You et al. (2018; 2019). Second, absolute income has a negative effect on happiness, e.g., Haring et al. (1984), Ng and Wang (1993), Oswald (1997). Third, researchers by scholars such as Frey et al. (2002), Run (2012), and Wu (2016) concluded that absolute income does not affect happiness. Forth, the effect of absolute income on happiness has an inverted "U"-shaped relationship, for example, Seligman et al. (2006), Tian, and Yang (2006). According to Maslow's hierarchy of needs theory, the most basic underlying human needs are physiological needs, and the satisfaction of physiological needs requires the support of economic income, so economic factors always have a fundamental role in residents' happiness (Zhang et al. 2011; Zhang et al. 2017). In contrast to developed countries, where the impact of absolute income on happiness weakens when basic physiological needs are met, the overall economy in China, especially in rural areas, is still at a relatively low level, and absolute income still plays a decisive role in achieving basic physiological material needs of rural residents (Kang 2021). Meanwhile, studies have confirmed that the marginal contribution of absolute income growth to the improvement of Chinese farmers' SWB remains significant (Ye et al. 2017). Consequently, this paper argues that absolute income has a positive contribution to the SWB of rural residents.

A review of the existing literature shows that studies that consider ICT or income on residents' SWB separately are common, but there is a lack of researches that unifies ICT and income into a theoretical explanatory framework for SWB. This paper argues that the gradual penetration of ICT, mediated by smartphones and computers, into rural areas and agriculture has changed the traditional lifestyles, entertainment, and consumption concepts of rural residents, which directly affects their SWB. ICT as a medium of social interaction helps to improve residents' social interaction, enhance their self-efficacy, and reduce their stress and depression levels (Shaw and Gant 2002). The Internet also provides a platform to express public opinion and reflect public sentiment, expands democratic participation, and improves residents' sense of fairness and satisfaction (Su and Huang 2015). In addition, the popularization and application of ICT have accelerated the flow of information in rural areas, significantly reduced the cost of information transmission and search, and can break the information asymmetry barrier (Aker et al. 2016), and it can significantly increase the absolute income of rural residents and indirectly improve their SWB. The theoretical framework of "ICT → income → farmers' SWB" (as shown in Figure 1) is constructed and the following research hypotheses are proposed.

Hypotheses2: ICT application can indirectly improve farmers' SWB by increasing farmers' absolute income.

Hypotheses3: ICT application can indirectly improve farmers' SWB by increasing farmers' relative income.

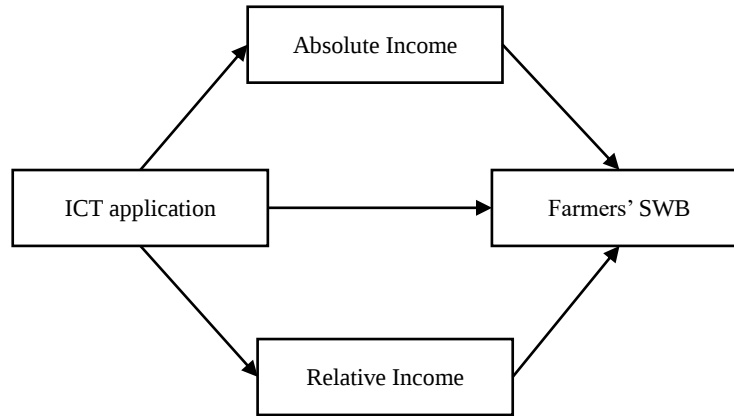


Figure 1. Analytical framework for how ICT application affect farmers' SWB by absolute income and relative income

Method

Relative to the research results, farmers' SWB takes values from 1 to 10, which is typical of discrete sorted data, if using OLS regression estimation may lead to estimation bias (Chen 2014), but some scholars believe that there is no advantage or disadvantage between OLS estimation and Oprobit model as long as the model is set correctly (Angrist and Pischke 2008). Therefore, to facilitate comparison, we established both Oprobit and OLS models to analyze the total effect of informatization on the SWB of farm households and built a mediating effect model to analyze the underlying mechanism of the effect of ICT and income (absolute income and relative income) on the SWB of farm households.

The total effect of ICT on farmers' SWB

(1) Oprobit Model

Treating farmers' SWB according to ordered categorical variables, the Oprobit model was set up as follows:

$$Happiness_i^* = \alpha_0 + \beta_1 Inf_i + \lambda_1 X_i + \varepsilon_i \quad (1)$$

$$Happiness_i = \begin{cases} 1, & Happiness_i^* \leq C1 \\ 2, & C1 < Happiness_i^* \leq C2 \\ \vdots & \\ 10, & C9 \leq Happiness_i^* \end{cases} \quad (2)$$

In Eq. (1), $Happiness_i^*$ is the latent variable of the SWB of farmer i , and there is a certain quantitative relationship with $Happiness_i$, as shown in Eq. (2), i.e., when the value is below the threshold $C1$, the SWB of the farmer takes the value of 1; when the value is higher than $C1$ but lower than $C2$, the SWB of the farmer takes the value of 2; and so on, when the value is higher than $C9$, the SWB of the farmer takes the value of 10; Inf_i is the information level of farmer i ; X_i is the control variables; β_1 , λ_1 are the parameters to be estimated, and ε_i are the random error of the model.

(2) OLS Model

The SWB of farmers was treated according to the base variables and an OLS linear model was set up as follows:

$$Happiness_i = \alpha_1 + \beta_2 Inf_i + \lambda_2 X_i + \nu_i \quad (3)$$

In Eq. (3), $Happiness_i$ is the SWB of farmer i , Inf_i is the information level of farmer i ; X_i is the control variables; β_2 , λ_2 are the parameter to be estimated, and ν_i is the random error of the model.

The mediation effect of income between ICT and farmers' SWB

Drawing on the modeling and testing process of Wen and Ye (2014), the mediating effect model is set up as follows:

$$Happiness_i^* (Happiness_i) = \alpha_2 + \beta_3 Inf_i + \lambda_3 X_i + \nu_{1i} \quad (4)$$

$$Income_i = \eta_0 + \eta_1 Inf_i + \eta_2 X_i + \nu_{2i} \quad (5)$$

$$Happiness_i^* (Happiness_i) = \alpha_3 + \beta_4 Inf_i + \eta_2 Income_i + \lambda_4 X_i + \nu_{2i} \quad (6)$$

In Eq.(4), Eq.(5) and Eq.(6), $Happiness_i$ is the SWB of farmer i , Inf_i is the information level of farmer i , the income level of farmer i is $Income_i$, including the absolute and relative income levels, X_i are control variables, λ_3 , λ_1 and λ_4 are the coefficients to be estimated for the variables. Eq. (4), β_3 is the total effect of ICT on the SWB of the farmer. In Eq. (6), β_4 is the direct effect of ICT on farmers' SWB.

Data sources and descriptive statistics

Data

In this paper, we used multi-stage sampling techniques to collect the samples. In the first stage, based on the intensity of apple production, six counties were selected: Qixia, Penglai, Baishui, Fuxian, Luochuan, and Jingning. In the second stage, six villages in each selected county were randomly selected. In the third stage, 20–21 households in each village were randomly selected, and 744 households were randomly sampled for interviews in total. Field data were collected from July 2018 to August 2018. The primary data were collected by household surveys (HHS) with a structured questionnaire. Based on the results obtained from the pre-test, necessary modifications were made to the questionnaire. Due to lack of major information, twenty-nine samples were excluded, and the final sample size was 715 completed questionnaires.

Variables selection

The dependent variable of this paper is SWB. The current methods on SWB measurement mainly include two types: one is multi-indicator and multi-temporal comprehensive evaluation, and the other is single-indicator and single-temporal evaluation. Among them, the first type of method takes into account the multidimensional and variable characteristics of SWB and has higher accuracy, but the implementation cost is larger. The second type of method is easy to operate, and the measurement reliability and validity are in the acceptable range (Diener 1999), which is in line with the level of scientific research (Easterlin 2003). Therefore, in this paper, a single-indicator and single-node measure were used to ask respondents "In general, how do you feel about your happiness", and the response options were set to assign a score from 1 to 10, with the higher the score, the stronger the SWB of the farmers.

From the perspective of ICT access, there is heterogeneity in the years of farmers'

smartphones and computer use. Seemingly, the ICT application of being diverse and can be classified into the years, frequency, and intensity of farmers' mobile Internet and fixed Internet use. Thus, in this paper we make a distinction in the variable setting of the ICT, i.e., the years of smartphone use (YSU), years of computer use (YCU), years of mobile Internet use (YMIU), years of fixed Internet use (YFIU), the frequency and intensity of mobile internet use (FMIU and IMIU) and the frequency and intensity of fixed internet use (FFIU and IFIU).

For the mediating variables, we used "current total household income" to measure absolute income level, and theoretically, the higher the absolute income, the higher SWB of farmers (Wu and Zhou 2017; Luo 2009). Furthermore, we drew on Guan Hao's (2010) method of measuring relative income by asking respondents "What level of income do you have in your village?" The options were assigned from 1 to 10, and the higher the score, the higher the relative income. Theoretically, relative income based on parallel or downward assumptions can help promote SWB.

Referring to previous theories and empirical experiences, in addition to informatization and income variables, we also controlled some variables that may have an impact on the SWB of farm households, as shown in Table 1. Specifically, they include gender, age, education level, health status, number of farm laborers, arable land area per capita, whether they are party members or village cadres, household non-farm employment, social trust, class status, class status expectation, sense of income fairness and household indebtedness and region dummies.

Table 1. Variable definitions and descriptive statistics

Variables	Definition and Description	Expected symbols
SWB	Ordered categorical variables, taking values from 1 to 10	—
Absolute income	Absolute income per capita household (Yuan/capita household)	+
Relative income	Ordered categorical variables, taking values from 1 to 10	+
YSU	2018 minus the year of smartphone initiation	+
YMIU	2018 minus year of mobile internet use	+
FMIU	Categorical variables, 1=Nearly never; 2=Several times a year; 3=At least once a month; 4=At least once a week; 5=Multiple times a week; 6=Almost every day	+
IMIU	The average number of hours spent online per day (hours)	+
YCU	2018 minus years of computer use	+
YFIU	2018 minus year fixed broadband Internet use started	+
FFIU	Categorical variables, 1=Nearly never; 2=Several times a year; 3=At least once a month; 4=At least once a week; 5=Multiple times a week; 6=Almost every day	+
IFIU	Average hours of use per week (hours)	+
Gender	1=male; 0=female	+/-
Age	Respondent's age (years)	+/-
Age squared	(Respondent's age/10) ²	+/-
Education level	Respondent's years of education (years)	+
Health status	1=very unhealthy; 2=unhealthy; 3=healthy; 4=very healthy	+
Number of farm laborers	Apple growing labor force in respondent households (persons)	+
Arable land area per capita	Apple hanging area/total household size	-
Party members or village cadres	1=yes; 0=no	+
Household Non-Farm Employment	The proportion of non-farm employed persons in the respondent's household (%)	-
Social trust	Do you think most people can be trusted? 1=Yes; 0=No	+
Class status	Respondent's perceived status within the village, taking values 1 to 10	+
Class status expectation	Respondent's perceived status within the village after 5 years taking values 1~10	+
Sense of income fairness	Your current income is reasonable compared to your ability. 1=Strongly disagree; 2=Disagree; 3=Rather agree; 4=Strongly agree	+
Household indebtedness	In the last 5 years, has the respondent's household borrowed money? 1=Yes; 0=No	-
Shaanxi	Dummy variable; 1 = yes, 0 = No	—
Gansu	Dummy variable; 1 = yes, 0 = No	—
IV_1	the proportion of 10 households near your home using mobile Internet	—
IV_2	the proportion of 10 households near your home using mobile payment	—
IV_3	the proportion of 10 households near your home using fixed broadband Internet	—

Descriptive statistics

Table 2 shows the results of descriptive statistics and correlation analysis of key variables. From the results of descriptive statistics, the SWB of apple growers was high, with a mean value of 7.260. For farmers who have access to smartphones. The FMIU is high, with an average value of 5.710, basically at the frequency level of "multiple times a week", but the IMIU is low,



with an average time of 1.777 hours per day. For farmers who have access to computers, although the average number of YCU is high, 7.030 and the average YFIU is 4.790, the FFIU is low, with an average value of 3.800, basically at the frequency level of "at least once a month". Besides, the IFIU is not high, with an average of 4.013 hours per week.

From the correlation statistics, absolute income and relative income are significantly correlated with SWB at the 1% level. Among the variables of ICT access, YSU is significantly correlated with SWB at the 1% level, and significantly correlated with absolute income and relative income at the 1% level. However, The YCU significantly correlated with absolute income at the 1% level, however, not significantly correlated with SWB. Among the variables of ICT application, YMIU is significantly correlated with SWB at the 5% level and significantly correlated with absolute income and relative income at the 1% level, YFIU is significantly correlated with SWB at the 1% level and significantly correlated with absolute income at the 1% level, and IFIU is significantly correlated with relative income at the 5% level.

Table 2. Descriptive statistics and correlation analysis of core variables

Variables	Mean	S.D.	SWB	Absolute income	Relative income
SWB	7.260	2.117	1	0.228***	0.311***
Absolute income	10.995	0.787	0.228***	1	0.288***
Relative income	5.42	1.776	0.311***	0.288***	1
YSU	3.300	3.194	0.119***	0.228***	0.156***
YMIU	3.610	2.505	0.118**	0.184***	0.131***
FMIU	5.710	0.849	0.048	0.087	0.019
IMIU	1.777	1.543	0.040	0.071	0.048
YCU	7.030	3.816	0.103	0.163***	-0.016
YFIU	4.790	3.788	0.161***	0.219***	0.051
FFIU	3.800	1.479	0.021	0.110	-0.014
IFIU	4.013	8.466	0.122	0.121	0.210**

Note: Correlation analysis was performed using Person correlation coefficient; ** $p < 0.05$, *** $p < 0.01$, two-tailed test.

Empirical Results

Basic regression results

In this paper, Oprobit estimation and OLS estimation of equation (1) and equation (3) were conducted using stata15.0 software to analyze the total effect of information technology access level and information technology application level on farmers' SWB (the results are shown in Table 3).

From the regression results, in both the Oprobit model and the OLS regression model, the YSU has a positive effect on farmers' SWB, and it is significant at the 1% level, indicating that mobile terminal information technology access can significantly improve farmers' SWB. The positive effect of YMIU on farmers' SWB is significant at least at the 5% level, indicating that mobile terminal information technology applications can significantly improve farmers' SWB. However, the positive effect of YCU and YFIU on farmers' SWB are not significant in the basic regression model.

Among the controlled variables, age has a significant positive effect on farmers' SWB, but its squared term has a significant negative effect on SWB, indicating that the effect of age on farmers' SWB has an "inverted U-shaped" distribution, which is contrary to the results of Zhu and Leng (2017; 2018). Education level has a significant positive effect on farmers' SWB, and it is significant at least at the 10% level, indicating that years of education can significantly improve farmers' SWB. Health status has a positive effect on farmers' SWB, and is significant at least at the 10% level, indicating that physical health can significantly improve farmers' SWB. Household employment has a negative effect on the SWB of farm households and is significant in some regression models, indicating that the higher the proportion of non-farm employment



in the household, the lower the SWB of farm households instead. The possible reasons are: first, the outflow of non-farm employed labor increases the intensity of farming for the labor force left behind, second, non-farm employment makes the members within the household spend less time together and the spiritual comfort welfare decreases. Social trust has a positive effect on farmers' SWB and is significant in some of the regression models, indicating that social trust perceptions can significantly increase farmers' SWB. The perception of class status has a positive effect on farmers' SWB and is significant at least at the 5% level, indicating that the higher farmers position themselves in terms of class status, the greater their well-being. Class status expectation has a positive effect on farmers' SWB and is significant in some regression models, indicating that the higher farmers' class status expectation is, the stronger their well-being is. The sense of income fairness has a positive effect on farmers' SWB, and all of them are significant at the 1% level, indicating that the higher farmers' recognition of the reasonableness of income distribution, the stronger their well-being.

Table 3. The effect of ICT on farmers' SWB: Oprobit and OLS estimation results

Variable	SWB	SWB						
	(Oprobit	(OLS						
	Model)	model)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
YSU	0.043*** (3.22)				0.076*** (3.30)			
YMIU		0.056*** (2.72)				0.088** (2.60)		
YCU			0.003 (0.31)				0.006 (0.35)	
YFIU				0.017 (1.48)				0.030 (1.49)
Gender	0.210 (1.42)	-0.072 (-0.38)	0.212 (1.53)	0.222 (1.60)	0.389 (1.52)	-0.071 (-0.22)	0.412 (1.63)	0.428* (1.70)
Age	0.038 (1.05)	0.195*** (3.75)	0.028 (0.78)	0.027 (0.76)	0.067 (1.01)	0.315*** (3.54)	0.048 (0.74)	0.047 (0.72)
Age squared	-1.231 (-0.63)	- 10.350*** (-3.57)	-0.019 (-0.53)	-0.017 (-0.47)	-2.025 (-0.58)	- 16.609*** (-3.36)	-0.030 (-0.46)	-0.026 (-0.40)
Education level	0.021 (1.31)	0.062*** (3.11)	0.024 (1.50)	0.022 (1.41)	0.051* (1.70)	0.125*** (3.31)	0.056* (1.87)	0.054* (1.79)
Health status	0.203*** (3.17)	0.140* (1.72)	0.203*** (3.15)	0.206*** (3.20)	0.405*** (3.40)	0.269* (1.89)	0.407*** (3.39)	0.411*** (3.42)
Number of farm laborers	-0.030 (-0.40)	0.035 (0.36)	-0.032 (-0.41)	-0.045 (-0.57)	-0.051 (-0.37)	0.066 (0.41)	-0.056 (-0.39)	-0.076 (-0.54)
arable land area per capita	0.009 (0.40)	-0.033 (-1.13)	0.014 (0.59)	0.011 (0.45)	0.028 (0.68)	-0.041 (-0.87)	0.036 (0.85)	0.030 (0.72)
Party members or village cadres	0.005 (0.05)	-0.043 (-0.36)	0.026 (0.25)	0.015 (0.14)	0.009 (0.05)	-0.060 (-0.31)	0.047 (0.25)	0.027 (0.15)
Household non-farm employment	-0.151 (-0.63)	-0.518** (-1.99)	-0.075 (-0.32)	-0.109 (-0.47)	-0.188 (-0.44)	-0.805* (-1.84)	-0.058 (-0.14)	-0.120 (-0.28)
social trust	0.197**	0.125	0.196**	0.190**	0.414**	0.256	0.413**	0.402**



	(2.18)	(1.06)	(2.17)	(2.11)	(2.53)	(1.26)	(2.50)	(2.44)
Class status	0.084**	0.117**	0.085**	0.084**	0.158**	0.203**	0.161**	0.160**
	(2.27)	(2.57)	(2.28)	(2.26)	(2.31)	(2.52)	(2.33)	(2.31)
Class status	0.091***	0.077*	0.092***	0.094***	0.157**	0.119	0.159**	0.161**
expectation	(2.71)	(1.79)	(2.74)	(2.77)	(2.51)	(1.54)	(2.53)	(2.56)
Sense of	0.153***	0.186***	0.158***	0.155***	0.264***	0.297***	0.275***	0.269***
income	(3.45)	(3.30)	(3.56)	(3.48)	(3.29)	(3.12)	(3.40)	(3.32)
fairness								
Household	-0.060	0.059	-0.065	-0.058	-0.118	0.118	-0.129	-0.116
indebtedness	(-0.73)	(0.57)	(-0.79)	(-0.71)	(-0.79)	(0.68)	(-0.86)	(-0.78)
Region	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
dummy								
Constant	—	—	—	—	-0.125	-6.529**	0.857	0.764
					(-0.06)	(-2.41)	(0.47)	(0.42)
Pseudo R ² /	0.0616	0.0713	0.0583	0.0590	0.2257	0.2436	0.2159	0.2181
R ²								

Note: *p < 0.1, ** p < 0.05, *** p < 0.01; t values under robust standard errors are shown in parentheses.

Endogenous Analysis

According to the existing theoretical and empirical experiences, ICT may be endogenous variables. Firstly, some variables that affect both ICT and farmers' SWB may be missed in the model, such as respondents' living habits and ability to accept new things (Zhu and Leng 2018). Secondly, SWB is a subjective evaluation, which may result in measurement errors due to differences in farmers' perceptions of happiness. Thirdly, ICT may have an inverse causal relationship with SWB, i.e., farmers with higher well-being may also have higher levels of informatization.

Given this, this paper proposes to use instrumental variables to correct the endogeneity problem, nevertheless, the partial variables of farmers' SWB and ICT are categorical discrete variables, the traditional two-stage least squares method of instrumental variables may fail in the estimation process (Qing and Zheng 2016). So, the conditional mixed process method (CMP) proposed by Roodman (2011), which can effectively solve the discontinuity problem of the variables, is used to re-estimate the model. The specific estimation process is as follows: at the first stage, we need to find the instrumental variables of ICT variables and test their correlation; at the second stage, the instrumental variables are brought into the model for regression, and test the endogeneity of ICT variables based on the parameter atanhrho_{12} value. If the endogeneity test parameter atanhrho_{12} value is significantly different from zero, it indicates that the ICT variables are endogenous and the CMP estimation result is better than the Oprobit and OLS estimation result.

In this paper, "the proportion of 10 households near your home using mobile Internet " is used as an instrumental variable for the YMU and YMIU, "the proportion of 10 households near your home using mobile payment" was used as an instrumental variable for the YCU, "the proportion of 10 households near your home using mobile payment " and " the proportion of 10 households near your home using fixed broadband Internet " are used as the instrumental variables for the YFIU. The model is re-estimated using the CMP estimation method.

In terms of the regression results (Stage I) in Table 4, it is clear that the endogeneity test parameter values are all significantly different from zero, indicating that YSU, YMIU, YCU and YFIU are all endogenous variables in the basic model and the CMP estimation results are better than the Oprobit model. So, the paper analyzes the impact of YSU, YMIU, YCU and YFIU on farmers' SWB based on the CMP model. The results of Table 4 (Stage II) show that, considering the endogeneity bias of ICT application, both YSU and YMIU have a positive effect

on farmers' SWB at the 1% level while both YCU and YFIU have a positive effect on farmers' SWB at the 5% level. The conclusions mean that, the smart mobile use years, mobile Internet use years, computer use years and fixed broadband Internet use years all improve farmers' SWB. In addition, estimated results of controlled variables remain largely consistent with the basic model. So, the results of controlled variables are not reported here again due to space limitations.

Table 4. Effect of the ICT application on farmers' SWB with CMP-Oprobit model

SWB (CMP-Oprobit)					
Variables	Stage I	Stage II	Variables	Stage I	Stage II
YSU		0.215*** (3.23)	YMIU		0.237*** (2.96)
IV_1	0.019*** (4.49)		IV_1	0.019*** (5.34)	
Controlled variables	controlled	controlled	Controlled variables	controlled	controlled
Region dummy	controlled	controlled	Region dummy	controlled	controlled
Constant	—	9.756*** (3.29)	Constant	—	12.380*** (5.21)
<i>atanhrho_12</i>	-0.544** (-2.08)		<i>atanhrho_12</i>	-0.419* (-1.93)	
Wald test	710.31***		Wald test	765.07***	
YCU		0.109** (2.02)	YFIU		0.125** (2.21)
IV_2	0.026*** (3.83)		IV_2	0.019*** (3.25)	
			IV_3	0.011* (1.82)	
Controlled variables	controlled	controlled	Controlled variables	controlled	controlled
Region dummy	controlled	controlled	Region dummy	controlled	controlled
Constant	—	0.643 (0.18)	Constant	—	1.608 (0.54)
<i>atanhrho_12</i>	-0.442* (-1.77)		<i>atanhrho_12</i>	-0.395* (-1.73)	
Wald test	579.53***		Wald test	562.93***	

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; z values under robust standard errors are reported in parentheses.

Further Discussion

As shown above the paper, the impact of ICT on farmers' SWB is positive significantly in terms of ICT access and application years. However, the ICT application frequency and intensity of each individual may be heterogeneous. Based on this, this paper further analyzes and discusses the effects of ICT application frequency and intensity (FMIU, MIU, FFIU, IFIU) on farmers' SWB (as shown in Table 5). Considering the endogeneity of FMIU, FFIU, IMIU, and IFIU, CMP is used to improve the accuracy of causality identification and used "the proportion of 10 households near your home using mobile Internet" as the instrumental variable for FMIU and IMIU, "the proportion of 10 households near your home using fixed broadband Internet" as the instrumental variable for FFIU and IFIU.

In terms of the regression results (Stage I) in Table 5, it is clear that the endogeneity test parameter values are all significantly different from zero except FMIU and IMIU, indicating that FFIU and IFIU are all endogenous variables in the basic model and the CMP estimation results are better than the Oprobit model. So, the paper analyzes the impact of FMIU and IMIU on farmers' SWB based on the Oprobit model while analyzes the impact of FFIU and IFIU based on CMP model. The results in Table 5 show that considering the endogeneity of ICT application frequency and intensity, FMIU and IMIU have no significant effect on farmers' SWB, while FFIU and IFIU have positive effects on farmers' SWB at the 10% and 1% significant level, respectively. The results indicate that fixed broadband Internet application frequency and fixed broadband Internet application intensity all significantly improve farmers' SWB, but the mobile Internet application frequency and intensity have not worked on the whole.

Table 5. The impact of ICT application frequency and intensity on farmers' SWB

SWB (CMP-Oprobit or Oprobit)					
Variable	CMP Stage I	Oprobit	Variable	CMP Stage I	Oprobit
FMIU		0.145 (0.97)	IMIU		0.024 (0.63)
IV_1	0.009*** (3.04)		IV_1	0.009*** (3.04)	
Controlled variables	controlled	controlled	Controlled variables	controlled	controlled
Region dummy	controlled	controlled	Region dummy	controlled	controlled
Constant	—	—	Constant	—	7.887*** (4.40)
<i>atanhrho_12</i>	-0.173 (-0.90)		<i>atanhrho_12</i>	-0.604 (-1.49)	
Wald test	154.91***		Wald test	305.36***	
Variable	Stage I	Stage II	Variable	Stage I	Stage II
FFIU		0.282* (1.81)	IFIU		0.109*** (3.48)
IV_3	0.021*** (4.31)		IV_3	0.050** (2.34)	
Controlled variables	controlled	controlled	Controlled variables	controlled	controlled
Region dummy	controlled	controlled	Region dummy	controlled	controlled
Constant	—	—	Constant	—	36.757 (1.05)
<i>atanhrho_12</i>	-0.441* (-1.82)		<i>atanhrho_12</i>	-1.016* (-1.90)	
Wald test	132.77***		Wald test	696.49***	

Note: * $p < 0.1$, ** $p < 0.05$ and *** $p < 0.01$; z values under robust standard errors are reported in parentheses.

Mechanism analysis

To further prove the mechanism of the influence of ICT application on the farmers' SWB, this paper uses the mediation effect model and the Bootstrap method to analyze the mediation

effect of ICT on the farmers' SWB by the absolute income. The estimated results are as followed in Table 6.

According to the results in Table 6, in Path A, Path C and Path D, both the indirect and direct effects are significantly positive at the 5% level, indicating that absolute income plays the partial mediation role in the relation of YSU, YMIU, YFIU and farmers' SWB. These conclusions mean that, smart mobile use years, mobile Internet use years and fixed broadband Internet use years not only improve farmers' SWB directly but also improve farmers' SWB indirectly by increasing the absolute income. In Path B, the direct effect coefficient is positive but insignificant, while the indirect effect coefficient is positive and significant at the 5% level, indicating that absolute income fully mediates the relationship between YCU and farmers' SWB. This conclusion means that, the computer use years improve farmers' SWB indirectly by increasing the absolute income.

Table 6. The mediation effect of absolute income in the relation of ICT application and farmers' SWB

Path	Effect		(Boot) SE	(Boot) LLCI	(Boot) ULCI
A. YSU→ Absolute income→ SWB	dir_eff	0.0466	0.0221	0.0026	0.0882
	Ind_eff	0.0321	0.0078	0.0186	0.0504
B. YCU→ Absolute income→ SWB	dir_eff	0.0197	0.0165	-0.0133	0.0509
	ind_eff	0.0283	0.0067	0.0173	0.0422
C. YMIU→ Absolute income→ SWB	dir_eff	0.0647	0.0286	0.0102	0.1180
	ind_eff	0.0400	0.0101	0.0235	0.0612
D. YFIU→ Absolute income→ SWB	dir_eff	0.0415	0.0187	0.0051	0.0791
	ind_eff	0.0332	0.0077	0.0208	0.0495

Note: The table shows the estimation results at 95% confidence level for replications of 1000 times; if the deviation-corrected confidence interval does not contain the value of 0, then the direct or indirect effect is significant, otherwise it is not significant.

Some related researches indicate that, the residents' well-being largely depend on others' income in addition to their absolute income (Wu and Zhou 2017; Luo 2009; Chen et al. 2016). Accordingly, does ICT application indirectly affect farmers' SWB by influencing their relative income? To further answer this question, this paper used the mediation effect model and Bootstrap method to prove the internal influence mechanism between ICT application and farmers' SWB. The results are as followed in Table 7.

According to the results in Table 7, in Path a, Path c and Path d, both the indirect and direct effects are significantly positive at the 5% level, indicating that relative income plays the partial mediation role in the relation of YSU, YMIU, YFIU and farmers' SWB. These conclusions

mean that, smart mobile use years, mobile Internet use years and fixed broadband Internet use years not only improve farmers' SWB directly but also improve farmers' SWB indirectly by increasing farmers' relative income. In Path b, the direct effect coefficient is positive but insignificant, while the indirect effect coefficient is positive and significant at the 5% level, indicating that relative income fully mediates the relationship between YCU and farmers' SWB. This conclusion means that, the computer use years improve farmers' SWB indirectly by increasing farmers' relative income.

Table 7. The mediation effect of relative income in the relation of ICT application and farmers' SWB

Path	Effect	(Boot) SE	(Boot) LLCI	(Boot) ULCI
a. YSU→ Relative income→ SWB	dir_eff	0.0479	0.0221	0.0042
	Ind_eff	0.0309	0.0092	0.0148
b. YCU→ Relative income→ SWB	dir_eff	0.0244	0.0169	-0.0100
	ind_eff	0.0236	0.0070	0.0109
c. YMIU→ Relative income→ SWB	dir_eff	0.0657	0.0265	0.0157
	ind_eff	0.0391	0.0118	0.0185
d. YFIU→ Relative income→ SWB	dir_eff	0.0512	0.0193	0.0148
	ind_eff	0.0236	0.0078	0.0095

Note: The table shows the estimation results at 95% confidence level for replications of 1000 times; if the deviation-corrected confidence interval does not contain the value of 0, then the direct or indirect effect is significant, otherwise it is not significant.

Conclusions and Policy Implications

On the construction of the theoretical analysis framework “ICT→ income (absolute income and relative income) →farmers' SWB”, the micro farmers survey data in apple main production areas are used to analyze the total effects of ICT application on farmers' SWB. On the basis, we use the mediation effect model and Bootstrap method to analyze the indirect effect of income (absolute income and relative income) between ICT application and farmers' SWB. The conclusions are as followed:

Firstly, considering the endogeneity of ICT application, the smart mobile use years, mobile Internet use years, computer use years and fixed broadband Internet use years all improve farmers' SWB. In addition, age, education level, health status, non-farm employment, social trust, class status perception, class status expectation, and income equity perception were also important factors affecting farmers' SWB.

Secondly, considering the endogeneity of ICT application frequency and intensity, fixed

broadband Internet application frequency and fixed broadband Internet application intensity all significantly improve farmers' SWB, but the mobile Internet application intensity and the mobile Internet application frequency have not worked on the whole.

Thirdly, the smart mobile use years, mobile Internet use years and fixed broadband Internet use years not only improve farmers' SWB directly but also improve farmers' SWB indirectly by increasing farmer' absolute income and relative income, while the computer use years only improve farmers' SWB indirectly by increasing farmers' absolute income and relative income.

Based on the above conclusions, the policy recommendations of this paper are to continuously promote the project of "information going to the countryside and entering the household" and reduce the access threshold of farmers' ICT applications. Furthermore, building a comprehensive service platform for rural communities, enriching farmers' information access content and channels, as well as increasing the frequency and intensity of ICT application. Last but not least, giving full play to the function of ICT application to increase farmers' income, and improve farmers' subjective well-being by increasing farmers' income.

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