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Information and communication technology impact on vegetable farmers' transaction costs: evidence from China

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ABSTRACT: *This study empirically examined the impact of information and communication technology (ICT) on transaction costs in the sales stage from three dimensions of information costs, negotiation costs, and enforcing costs. The micro-sampling survey data was collected from 1338 vegetable growers in Hebei and Shandong provinces of China. We applied propensity score matching to examine the facts that adopting ICT can significantly decrease farmers' information costs through improving information accuracy and reducing searching difficulty, and reducing negotiation costs by lowering the negotiation time. However, using ICT has no significant impact on default risk and transportation difficulty thus enforcing costs of farmers have a slight difference. Therefore, a coordinated set of policies including cultivating farmers' ability to obtain information, advancing the construction of vegetable distribution channels and improving the market supervision mechanism are put forward.*
Key words: *information and communication technology, vegetable farmers, transaction costs, propensity score matching.*

O impacto da tecnologia da informação e comunicação nos custos de transação dos produtores de vegetais: evidências da China

RESUMO: *Este estudo examina empiricamente o impacto da tecnologia da informação e comunicação (TIC) nos custos de transação no estágio de vendas a partir de três dimensões de custos de informação, custos de negociação e custos de execução. Os dados da pesquisa de micro-amostragem foram coletados de 1338 produtores de vegetais nas províncias de Hebei e Shandong, na China. Aplicamos a correspondência de pontuação de propensão para examinar os fatos de que a adoção de TIC pode diminuir significativamente os custos de informação dos agricultores, melhorando a precisão das informações e reduzindo a dificuldade de pesquisa, e reduzir os custos de negociação, diminuindo o tempo de negociação. No entanto, o uso de TIC não tem impacto significativo no risco de inadimplência e na dificuldade de transporte, portanto, os custos de fiscalização dos agricultores têm uma ligeira diferença. Por conseguinte, um conjunto coordenado de políticas, incluindo o cultivo da capacidade dos agricultores de obter informações, o avanço na construção de canais de distribuição de vegetais e a melhoria do mecanismo de supervisão do mercado são apresentados.*
Palavras-chave: *tecnologia da informação e comunicação, agricultores de vegetais, custosde transação, correspondência de pontuação de propensão.*

INTRODUCTION

China has to produce food for one-fifth of the world population. Thus, food security is considered highly important in the development process of China. Besides, in the current developmental paradigm many labor shifts from the agriculture sector to other sectors of the economy (SU et al., 2011; NBSC, 2011). Horticulture is the main sub-sector of the agriculture sector in China. The major crops of the horticulture sector are vegetables, fruits, melons, mushrooms, etc. In vegetable production, China is the leading producer in the world (WU, 2014). In 2013, China has produced 700 million tons of vegetables which are half of the world's overall annual production (CHEN et al., 2014). More importantly, in 2016, vegetable production has been increased by 88.2% compared to 2000 in China. For comparison, China has produced

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5 times more vegetables than India and 16 times more than the United States (WU, 2014). This means that the vegetable industry has significantly contributed to this sector. The development of this industry can promote the adjustment of agricultural structure, optimizing the dietary structure of residents, increase farmers' income and improve their living standards. However, due to short shelf life, high commodity rate and frequent vegetables transactions, farmers faced higher entry threshold and circulation constraints when selling vegetables. Therefore, transaction costs have become the primary factor that hinders farmers from entering competitive markets (BIRTHAL et al., 2005; WEN & WU, 2016).

The transaction cost method to the theory of the firm was developed by COASE (1937). Transaction cost refers to the cost incurred that do not accrue to any participant of the transaction. Generally, it is a sunk cost when economic activity takes place in a market such as a capture, transfer, and protection of ownership rights of economic assets (WILLIAMSON, 1979; WILLIAMSON et al., 1975, HARDT, 2009). Transaction costs are based on the assumption that people are influenced by competitive self-interest. The nature of this cost encompassing bargaining, price mechanism, uncertain market condition, and uncertain market information. These costs are associated with looking for relevant information and meeting with agents with whom the transaction would take place (HOBBS, 1997, HOLLOWAY et al., 2000, SHELANSKI & KLEIN, 1995). Furthermore, transaction costs are considered as the costs of obtaining accurate market information (COASE, 1960). Therefore, it is mandatory to reduce the transaction costs because it would improve the farmer's capability of obtaining accurate information. The past studies such as PINGALI et al. (2005), KIRSTEN & SARTORIUS (2002), CUEVAS (2014), and HOU & HUO (2017) suggest that well-informed market information decreases transaction costs. Further, well-informed market information encourages the farmers to actively participate in the market. In contrast, the absence of well-informed market information obstructs the farmers to participate actively in the market. Besides, it enhanced the bargaining, screening and searching costs. It is the main concept in the agriculture sector and is utilized for mitigating market failures. The cost of exchange, using the price mechanism, and searching for information are the various type and patterns of the transaction cost. It has been involved in the running of an economic system and the transfer of ownership. It is measured as a direct cost when a market transaction may occur. The transaction costs have a direct negative impact on farmers. To protect farmers from negative impacts and to reduce transaction cost market intervene to provide acceptable market information on time. These involvements stimulate the farmer to participate actively in the market. To improve the information access methods and reduce the transaction costs of farmers, the government of China at all levels has invested a great deal of enthusiasm, including promoting rural ICT construction to narrow the urban-rural digital gap. However, from the current promotion situation, farmers do not show high demand for emerging communication technologies. So, the transaction costs are still high and the problems remain unresolved.

Previous studies suggested that farmers heavily rely on traditional information channels such as mass media and social networks to obtain agricultural information (DAUDU et al., 2009; LAWRENCIA, 2017), but due to the slow transmission speed and low information quality, the transaction costs of farmers are still costly (AKER, 2011; ZANELLO, 2012). Since the 1990s, Information and Communication Technology (ICT), represented by mobile phones and the internet, has become the most influential information technology and is profoundly changing the way farmers access information (DEICHMANN et al., 2016). The consistent utilization of ICT improves information sharing as a result it enhanced the welfare in developing nations and attains the target of high economic growth (YONAZI et al., 2012; BAUMÜLLER, 2018).

Factually, with the continuous use of ICT in agriculture sector yet farmer has not earned high income and has not gained high production. This means that mainly in developing countries obstruction to the adoption of ICT and mobile phones-based services in agriculture still exist (AKER & MBITI, 2010; ARD, 2011). In this scenario, many digitalization initiatives have been taken for the improvement of agriculture growers in developing countries. Nevertheless, digital culture in the agriculture sector has not been developed due to poor connection, lack of adoption of ICT usage and low purchasing power of digital application. The absence of digital culture in agriculture would cause digital poverty (BAUMÜLLER, 2015; COURTOIS & SUBERVIE, 2014; TATA & MCNAMARA, 2018; BAUMÜLLER, 2018; SALEMINK et al., 2015; MAY, 2012). To protect the farmers from digital poverty the concurrent issues related to ICT should be removed with help of digital initiatives (AKER et

al., 2016; MAY & DIGA, 2015). It is undeniable that worldwide the smart farming using ICT mechanism has been encouraged for development initiatives. Moreover, the provision of ICT to the farmers expedites the process of information accessibility and enhances their capability and mental horizon by sharing information with each other's (GRIFFITH et al., 2013; ARD, 2011).

In this context, AKER (2011) investigated the relationship between the adoption of ICT and the transaction costs of farmers and revealed that using modern communication technology reduced the costs of information. Further, ZANELLO & SRINIVASAN (2014) examined that ICT has significant effects on overcoming information barriers, and improving information quality. Further, HOU & HUO (2017) investigated that the internet improved farmers' availability of information and reduce the information cost. EITZINGER et al. (2019) suggested that digital agriculture through the use of ICT can assist farmers while sharing their experiences with people having expertise and interest in this area.

Moreover, ZHANG et al. (2016) stated that ICT played a crucial role in the transformation of the agriculture sector of China while improving productivity along with social, economic and environmental sustainability. CHAULAGAIN (2014) highlighted that lack of information regarding technology and information gap lead farmers towards subsistence farming. In developing countries, farmers spend more income on ICT as highlighted by TIRKASO & HESS (2015). The authors of the study have explored the relationship between investments in ICT and market participation and their role in income generation. Their findings indicated that the income of the farmers is a key factor to be spent on more adoption of ICT. So, it is suggested that ICT adoption is highly significant for better agricultural production.

However, there are still some problems that exist which must be addressed. Firstly, previous studies directly related ICT to market behavior, but few on the transaction cost. They only focused on the impact of information acquisition methods on the choice of farmers' trading channels so our study attempts to close this gap by examining the interaction between ICT and transaction costs. Secondly, the existing research mostly used the probit model, ordinary least squares model, and some other traditional regression methods, whose shortcoming is that it is difficult for them to overcome the sample selection bias caused by heterogeneity and self-selectivity. To fill the gap, this study estimated the farmer's transaction cost by using the propensity score matching (PSM) approach, has an edge over other approaches and then analyzes the impact of ICT on transaction costs. Thirdly, previous studies exploring the impact of ICT adoption used mostly indicators such as ICT investment or ownership, which may be unsuitable for our study because farmers may use ICT for other purposes. Thus, we strictly define ICT adoption as using ICT (mobile phone and internet) to find information for the purpose of agricultural production. In this way, we can make sure that farmers' ICT use is closely linked to vegetable production. Besides, this study combines the quantitative analysis with qualitative analysis to seek the optimal information acquisition methods for farmers and provides the theoretical basis and policy recommendations for reducing vegetable transaction costs, stabilizing market prices and increasing farmers' income. The specific objectives were to find out the actual situation of farmers using ICT in China and how ICT adoption affected the transaction costs of farmers. Based on this, we found that adopting ICT can significantly decrease farmers' information costs and negotiation costs while it has no significant impact on their enforcing costs. So we can say that ICT has a significant impact on vegetable farmers' transaction costs. The remainder of the manuscript is structured as below: the next section presents the methodology of the study. The third section presents the results and discussion of the study. The last section concluded the results and suggested the policy implications of the study.

METHODOLOGY

Description of variables and data source

This study was conducted to investigate the impact of ICT on vegetable farmer's transaction costs in China. For this purpose, cross-sectional data were collected from the households of the vegetable growing farmers in Hebei and Shandong provinces of China in the year 2018. Figure 1 presents the map of the study area. Both Shandong and Hebei are well known for the remarkable growing vegetable provinces. The total output of these provinces has reached 23.81% of the vegetable planting area in China. For the data collection, this study has used a stratified random sampling technique. To ensure the quality of the survey, this study has initially carried out a preliminary investigation with the help of a carefully designed and formally structured questionnaire. We obtained information including householders' characteristics, production practice information, information access, regional infrastructure, and so on. After verification, a total of 1338 valid observations were obtained.

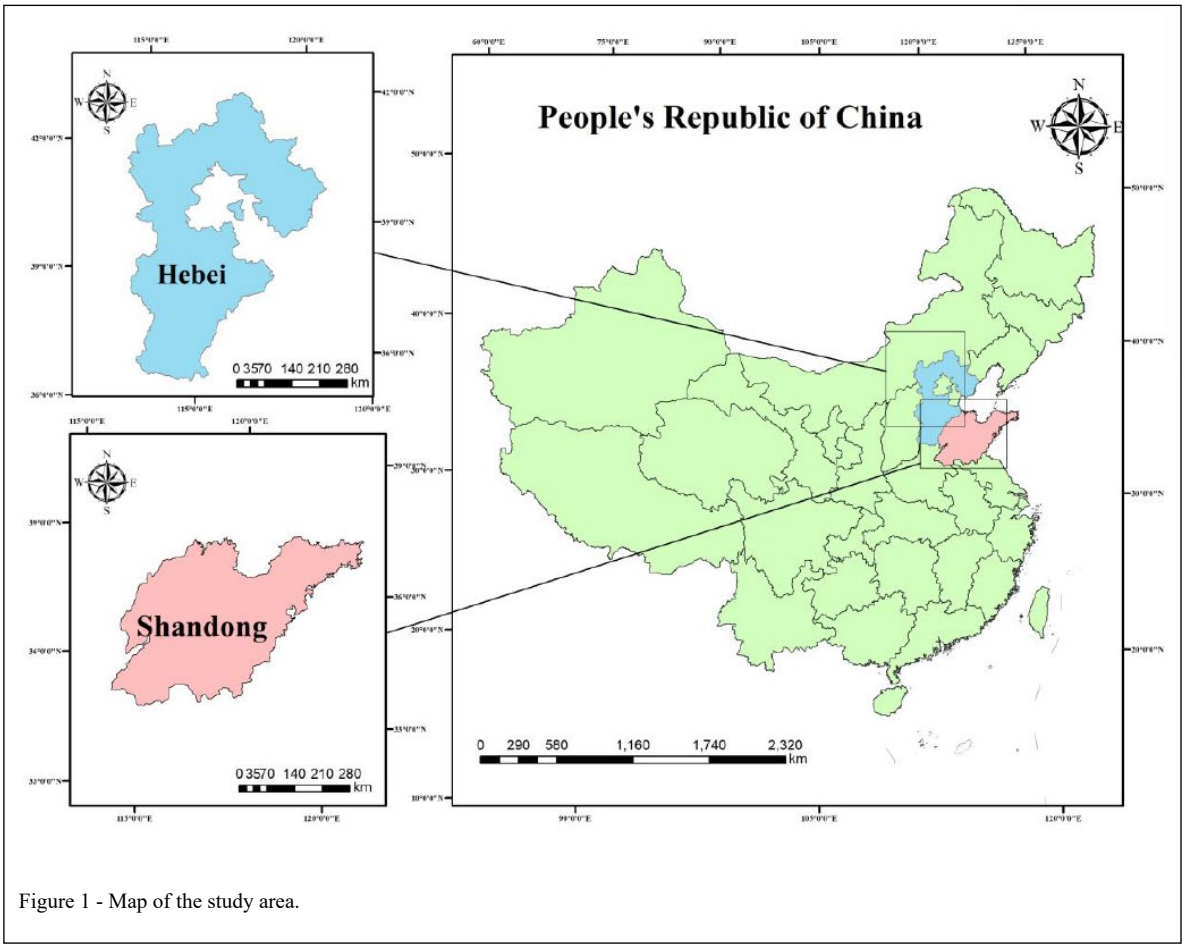

Figure 1 - Map of the study area.

Following the seminal research of WILLIAMSON (1986) and some other existing research, for instance, HOBBS (1997), QU et al. (2007), and HUANG et al. (2008), we also selected specific proxies to measure farmers' transaction costs from its three dimensions. These include information costs, negotiation costs and enforcing costs. The first set of variables is information costs and the selected proxies are searched difficulty and information accuracy. Search difficulty reflects the difficulty for farmers to search for information related to vegetable sales prices, policies and so on before farmers enter the market (WEN, 2011). Information accuracy reflects the results of farmers' information searching behavior (HOU & HUO, 2017). Generally, high search difficulty and low information accuracy indicate high information costs for farmers.

The second set of variables is negotiation costs and the two indicators of negotiation are time and contact frequency. This means that negotiation time with the buyers in the transaction (hour) and contact frequency with the buyers in the transaction. These variables are used as proxy variables for time costs and labor costs of the farmers and buyers respectively during the transaction negotiation process (HUANG et al., 2008). Long negotiation time and contact that is more frequent indicated high negotiation costs faced by farmers in the vegetable sales stage. The third set of variables is enforcing costs and the two indicators of default risk and transport difficulty were selected as proxy variables. Among them, the default risk was used to reflect the risk costs brought by the buyer's default in the execution of the transaction (SONG & QI, 2011). Transportation difficulty is used to reflect the costs of the actual implementation of the contract by the farmer (QU et al., 2007). If farmers bear higher default risks and transportation costs in transactions, this means that they are facing high enforcing costs in the vegetable sales stage.

There are four types of covariates in our study: The first is the characteristics of household variables, including age, education and experience of the farmers. The second is the characteristics of the family, including family burden ratio, per capita income, and market distance. The third is the characteristics of production, including land, labor and cooperative. The fourth covariates variable is the location employed as a dummy variable. It is important to mention that in this survey the total household income refers to the sum of all economic sources of each family, including planting, vegetables, forestry, working, breeding, business, enterprises and institutions, pensions, government subsidies, etc. Table 1 shows the selection and interpretation of each variable.

Empiricals Strategy

The choice of whether farmers use ICT is not random, and it is influenced by factors such as characteristics of farmers, family, and region, so it is self-selective. The difference in transaction costs between farmers using ICT and those not using ICT will lead to selection bias (WOOLDRIDGE, 2002), which may weaken the credibility of the estimated results. Therefore, this study used PSM to construct a counterfactual framework to study the impact of ICT on farmers' transaction costs. According to Rubin Causal Model (ROSENBAUM & RUBIN, 1983), this study divides sample households into a treatment group (farmers who use ICT; ICT) and a control group (farmers who do not use ICT; NICT). We use *i* to indicate the sample farmer and $D_i = \{0,1\}$ to indicate whether farmer i uses ICT. If one uses, $D_i = 1$; otherwise, $D_i = 0$. The y_{1i} and y_{0i} represent the transaction costs of the farmers in the treatment group and control group respectively. In the first step, we use the Logit Model to estimate the propensity score (P-score) of farmers. That is, given x_i, the conditional probability $p(x_i)$ of farmer *i* using ICT is estimated. The expression is:

$$p(x_i) \equiv p(D_i = 1 \mid x = x_i) \quad (1)$$

In the second step, we match the propensity score. The specific method of propensity score matching is not unique. In this study, we use the nearest neighbor matching method and then compare its results with kernel matching and caliper matching. This implies that, if the outcomes of the estimation are consistent with the results of two matching methods, then we would assume that estimated result are robust. After matching, the standard deviation S was used to test whether the distribution of the covariate x_i between the treatment group and the control group is uniform. The expression of S is:

$$S = \frac{|\bar{x}_{\text{treat}} - \bar{x}_{\text{control}}|}{\sqrt{\left(s^2_{x,\ \text{treat}} - s^2_{x,\ \text{control}}\right)/2}} \quad (2)$$

where $\bar{x}_{\text{treat}}$ and $\bar{x}_{\text{control}}$ represent the covariate mean of treatment and control groups; $s^2_{x,treat}$ and $s^2_{x,control}$ represent the covariate variance of the two groups. Generally, the standard deviations should not exceed 20% (ROSENBAUM & RUBIN, 1983). If not, we should return to the second step or even the first step to re-estimate the propensity score or change the matching method. In the third step, the average treatment effect (ATT) of the treatment group (ICT) is calculated according to the matching sample. The ATT can be written as:

$$\widehat{ATT} = E(y_{1i} - y_{0i} | D_i = 1) = \frac{1}{N_1}\sum_{i:D_I=1}(y_i - \hat{y}_{0i}) \quad (3)$$

where N_1 indicates the number of farmers in the treatment group, $\sum_{i:D_I=1}$ means summarize the households using the ICT: y_i indicates the transaction costs of the i^{th} farmer; $\hat{y}_{0i}$ indicates the estimates of transaction costs assuming that farmers using modern communications technologies do not use them. The data were analyzed by using statistical software STATA version 14.

RESULTS AND DISCUSSION

Descriptive statistics

The characteristics of the householders are shown in table 2. The average age of household farmers using ICT and those not using ICT were 47.13 and 53.32, respectively. The average years of education of the household farmers using ICT and not using ICT were 7.84 and 6.89, respectively. Further, the average years of the household farmers growing their vegetables using ICT and not using ICT were 24.18 and 29.67, respectively. These variables portray that the households have an aging trend and low education level, but they have rich experience in vegetable growing. Farmers using ICT had on average a younger age, higher education, and fewer years of vegetable cultivation than those in the NICT group. BEZA et al. (2018) focus on the use of the mobile phone by smallholder farmers in the provision of farm information along with how age and experiences affect the intention of the farmer while using the mobile phone. The age, as well as experience, reveals that young farmers gave more value to performance expectancy but the price is more important for those farmers who do not use mobile SMS.

Moreover, the per capita income (31,041.16 RMB) of farmers in the ICT group was higher than

Table 1 - Variable selection and description.

Variables	Interpretation
----------Outcome Variable----------	
Whether use ICT	Yes = 1; No = 0
----------Information costs----------	
Search difficulty (y_1)	Very easy=1; easy=2; general=3; difficult=4; very difficult=5
Information accuracy (y_2)	Very low=1; low=2; general=3; high=4; very high=5
Negotiation costs Negotiation time (y_3)	Negotiation time with the buyers in the transaction (hour)
Contact frequency (y_4)	Contact frequency with the buyers in the transaction
----------Enforcing costs----------	
Default risk (y_5)	Very less=1; less=2; general=3; many=4; very many=5
Transport difficulty (y_6)	Very easy=1; easy=2; general=3; difficult=4; very difficult=5
----------Covariates----------	
----------Characteristics of household----------	
Age (x_1)	Age of household (Year)
Education (x_2)	How many years has householder been educated (Year)
Experience (x_3)	How many years has householder been engaged in agricultural production (Year)
----------Characteristics of family----------	
Family burden ratio (x_4)	The ratio of the number of non-working people to the total number of households
Market distance (x_5)	The distance from family to the market (km)
Household income per capita (x_6)	The ratio of total income to family size (RMB)
----------Characteristics of production----------	
Labor (x_7)	The number of people who engaged in vegetable production
Land (x_8)	Vegetable acreage (ha)
Cooperative (x_9)	Join=1; Not join=0
Location	
Dummy Variable (x_{10})	Shandong=1; Hebei=0

Source: Author's calculation.

that of farmers in the NICT group (23,460.57 RMB). The average distance (2.10 km) between households in the ICT group and the market was shorter than that in the NICT group (2.53 km). The family burden ratio of the ICT group (0.40) was higher than that of the NICT group (0.37). That is, farmers with short distances and heavy family burdens tended to use ICT. From the perspective of production characteristics, there is little difference in the number of people in one household planting vegetables and the area of planting vegetables between them using ICT and not using ICT. On average, there are at least 2 persons in each household planting about 0.23-hectare land. In the 1338 samples, only 279 households joined the cooperative, suggesting a low degree of participation, among which, 165 households used ICT, accounting for 59.14% of the total number of farmers participating in the cooperative, indicating that the probability of farmers participating in the cooperative who use ICT was higher than those not using ICT. From the size of households who use ICT in 1338 samples, the Hebei province accounted for 42.45% (568) and Shandong province accounted for 57.55% (770). In Hebei, the number of farmers using ICT accounted for 24.47% (139) of the total sample and in Shandong, the number of farmers using ICT accounted for 52.21% (402) of the total sample. These results suggested that the number of people who use ICT in Shandong province is more than in Hebei province.

Results of table 2 show that searching for information is not a difficult thing for farmers but the information is not completely accurate. The average level of search difficulty of farmers in the ICT group was lower than that in the NICT group and the average level of information accuracy was higher than that in the NICT group. The negotiation time of farmers in the ICT group (0.21) was less than that in the NICT group

Table 2 - Descriptive statistics of the variables.

Variables	--------Total（1338)-------		---------ICT (541----------		---------NICT（797--------		diff
	Mean	SD	Mean	SD	Mean	SD	
Search difficulty (y_1)	2.3655	0.9162	2.3235	0.8675	2.3940	0.9473	-0.0705
Information accuracy (y_2)	3.0732	0.9992	3.1368	0.9980	3.0301	0.9982	0.1067*
Negotiation time (y_3)	0.3658	0.6572	0.2098	0.4690	0.4717	0.7406	-0.2619***
Contact frequency (y_4)	1.4689	1.5750	1.4852	1.7505	1.4579	1.4449	0.0273
Default risk (y_5)	1.9776	0.8054	1.8632	0.8627	2.0553	0.7548	-0.1921***
Transport difficulty (y_6)	1.8438	0.5713	1.7893	0.5709	1.8808	0.5689	-0.0915***
Age (x_1)	50.8199	9.8650	47.1294	9.7971	53.3249	9.0997	-6.1955***
Education (x_2)	7.2720	2.8336	7.8373	2.4296	6.8883	3.0194	0.949***
Experience (x_3)	27.4492	11.0797	24.1775	10.8420	29.6700	10.6881	-5.4925***
Family burden ratio (x_4)	0.3810	0.2325	0.4045	0.2180	0.3650	0.2407	0.0395***
Market distance (x_5)	2.3567	3.9556	2.1033	4.2128	2.5286	3.7640	-0.4253*
Household income (x_6)	26525.67	23486.220	31041.16	27444.39	23460.57	19805.890	7580.59***
Labor (x_7)	2.1398	0.6218	2.1922	0.6526	2.1041	0.5976	0.0881**
Land (x_8)	0.2379	0.2195	0.2360	0.1464	0.2391	0.2577	-0.0031
Cooperative (x_9)	0.2085	0.4064	0.3049	0.4608	0.1430	0.3503	0.1619***
Location (x_{10})	0.5755	0.4945	0.7431	0.4373	0.4617	0.4988	0.2814***

Source: Author's calculation.

Note: ***, **, and * indicate the significance of 1%, 5%, and 10% respectively; 1 USD was equal to 6.63 RMB at the end of year 2018.

(0.47), indicating that the use of ICT can significantly reduce the time spent in the negotiation between sample households and buyers. The average contact times between farmers in the ICT group and those in the NICT group were 1.49 times and 1.46 times respectively, indicating that each household had to negotiate once or twice to complete the transaction. The index of default risk and transportation difficulty are all less than 2, which indicated that there are few cases of buyers' default and it is not difficult to transport vegetables for farmers. These two indicators of the NICT group were slightly higher than that of the ICT group. This means that enforcing costs of the NICT group might be higher than the ICT group.

Logit regression

Likewise, the estimated results of the Logit model of PSM are presented in table 3. In the estimation of the Logit model of PSM, the farmers adopting and not adopting ICT was treated as dependent variable and influencing factors such as householder characteristics (age, education and experience), family characteristics (family burden ratio, per capita income, and market distance), production characteristics (land, labor and cooperative) and the location dummy variable, were treated as independent variables. Results showed that the education and age of the household have a positive and negative relationship with adopting ICT. Further, the households' experience has a positive influence on adopting ICT. These results suggested that the younger and better-educated householders have a higher probability to use ICT, which may be because younger and high-educated people have a strong ability to manipulate new technologies and search for new information. These research findings are consistent with findings of SMITH & KENNY. (2004), HUANG & ZHANG (2011), OLADELE (2015), and XIAO (2012).

In terms of family characteristic variables, household incomes per capita and market distance have a significant and positive effect on farmers adopting ICT, and the family burden ratio is not significant. Generally, the higher per capita income of the rural households is more inclined to use ICT. This may be because high-income households have the economic ability to learn and apply new technology. The longer the distance between family and the

Table 3 - The estimated results of the Logit model of PSM.

Variable	Coefficient	z	Variable	Coefficient	z
Age (x_1)	-0.0667***	-5.83	Labor (x_7)	0.2557**	2.49
Education (x_2)	0.0708***	2.89	Land (x_8)	-0.0280	-1.33
Experience (x_3)	0.0143	1.46	Cooperative (x_9)	0.7514***	4.98
Family burden ratio (x_4)	0.2123	0.69	Location Dummy Variable (x_{10})	0.9483***	5.96
Market distance (x_5)	0.0504***	2.91	Constant	0.9761	1.27
Household income per capita (x_6)	6.72e-06 **	2.02			
Log-Likelihood	777.9533		LR x^2	249.67	
Prob> x^2	0.0000		Pseudo R^2	0.1383	

Source: Author's calculation.

Note: ***, **, and * indicate the significance of 1%, 5%, and 10% respectively.

market, the more they are inclined to use ICT. It is because long-distance households cost much in terms of time, manpower, and transportation for searching information, thus make up for their geographical disadvantage by using ICT.

Among the production characteristic variables, labor and cooperation have a positive and significant relationship with the farmers' adoption of ICT, and the land is not significant. This indicated that families who have more people grow vegetables and join the cooperatives tend to use ICT. This is similar to that of WANG & HUO (2014), and LIU (2018). This may be because more people means more demand for information and agricultural cooperatives often provide information services through channels such as mobile phones and networks, which have increased their probability of using ICT.

Balance test

In this study, the one-to-one matching method in k-nearest matching (i.e., nearest-neighbor matching method) is used to match the characteristic variables of farmers. To ensure the reliability of our matching, it is necessary to test the balance of the covariates (characteristic variables) between the treatment group (ICT) and the control group (NICT). After matching, there should be no significant systematic differences in the covariates except for the differences in transaction costs between the two groups. The results of the balance test are shown in table 4.

It can be seen from table 4 that after matching, the standard deviation of the characteristic variables greatly reduced, and their absolute values are all reduced to below 20%. At the same time, the t-test results do not reject the null hypothesis that there is no systematic difference between the treatment group and the control group, indicating that the matching is successful, and using PSM corrects the bias between the farmers using ICT and not based on observables.

Average treatment effects

After we use the nearest neighbor matching method to estimate the propensity scores of the characteristic variables, the control group excluded 10 samples, and the treatment group excluded 22 samples. Thus, the total number of remaining samples was 1306.

The estimated results of the PSM method are shown in table 5. In terms of the impact of ICT on farmers' information costs, after matching, farmers using ICT significantly have higher information accuracy and lower search difficulty than those who are not using it. These showed that after considering the selective deviation of farmers, the adoption of ICT can help farmers to access information and improve the accuracy of the information they get. The reason may be that ICT has the advantage of high speed, timely delivery and wide coverage, which shortens the time and labor costs of vegetable farmers when searching for information. For example, both Shandong and Hebei Province have vegetable information websites, which regularly publish various kinds of information about vegetables such as market price and new regulations. By ICT, farmers can obtain the required information anytime and anywhere and

Table 4 - The balance test results of PSM.

Variable		-------Mean-------		Standard deviation (%)	Reduction in SD (%)	t-statistics
		ICT	NICT			
Age (x_1)	before	47.129	53.325	-65.5	98.9	-11.85***
	after	47.753	47.819	-0.7		-0.11
Education (x_2)	before	7.8373	6.8883	34.6	82.5	6.09***
	after	7.7630	7.5973	6.0		1.09
Experience (x_3)	before	24.177	29.670	-50.1	97.4	-9.17***
	after	24.778	24.634	1.3		0.23
Family burden ratio (x_4)	before	0.4045	0.3650	17.2	58.0	3.05***
	after	0.4001	0.4166	-7.2		-1.21
Market distance (x_5)	before	2.1033	2.5287	-10.6	65.4	-1.93*
	after	2.1126	1.9655	3.7		0.59
Household income per capita (x_6)	before	31041	23461	31.7	67.0	5.87***
	after	29595	32096	-10.5		-1.50
Labor (x_7)	before	2.1922	2.1041	14.1	65.0	2.55**
	after	2.1484	2.1175	4.9		0.86
Land (x_8)	before	0.2360	0.2391	-1.5	-207.7	-0.25
	after	0.2340	0.2345	4.6		1.18
Cooperative (x_9)	before	0.3050	0.1430	39.6	83.3	7.29***
	after	0.2775	0.3044	-6.6		-0.96
Location Dummy Variable (x_{10})	before	0.7431	0.4617	60.0	95.9	10.63***
	after	0.7341	0.7225	2.5		0.42

Source: Author's calculation.

Note: ***, **, and * indicate the significance of 1%, 5%, and 10% respectively.

then improve their transaction efficiency. Besides, different kinds of agricultural applications covering the market, policy, technology, and other information needed by many farmers are constantly emerging and bringing great convenience. This finding is supported by ZANELLO (2012). Therefore, it can be concluded that the use of ICT can help reduce the information costs of farmers.

In terms of negotiation costs, after matching, the negotiation time of the farmers using ICT was 0.10 hours less than that of the NICT group with a significant of 10%. These showed that after considering the selective deviation of farmers, the use of ICT has significantly reduced the negotiation time of farmers. The reason may be that ICT helps to increase the contact frequency between farmers and buyers while breaking the restrictions of location and time required for the transaction. According to our survey, the vegetable farmers who use ICT are more likely to form a close social network relationship with the buyers based on a more frequent connection. Therefore, it can be concluded that the use of ICT can help reduce the negotiation costs of vegetable farmers.

For farmer's enforcing costs, neither default risk nor transport difficulty passes the significance test after matching, which means that the use of ICT does not have a significant impact on enforcing costs after considering the selective bias of farmers. This may be because the two provinces of Hebei and Shandong, as the major provinces cultivating vegetables in China, have gradually formed a smooth vegetable sales channel and developed an effective market supervision system under government support. Therefore, the market has effectively put an end to default risk and malicious breach of contract, which can protect the interests of vegetable farmers and improve their participation in the market enthusiasm. Besides, the construction of infrastructure and the improvement of transportation channels have reduced the transportation costs and difficulties of farmers and formed a convenient

Table 5 - The estimated results of PSM.

----------Variable----------		ICT	NICT	ATT	t-statistics
Search difficulty (y_1)	before	2.3235	2.3940	-0.0705	-1.38
	after	2.3276	2.5453	-0.2177*** (0.0962)	-2.65
Information accuracy (y_2)	before	3.1368	3.0301	0.1067*	1.92
	after	3.1368	2.9383	0.1985** (0.1056)	2.27
Negotiation time (y_3)	before	0.2098	0.4717	-0.2619***	-7.29
	after	0.2164	0.3121	-0.0957* (0.0537)	-1.78
Contact frequency (y_4)	before	1.4852	1.4579	0.0273	0.31
	after	1.4884	1.3092	0.1792 (0.1269)	1.54
Default risk (y_5)	before	1.8632	2.0552	-0.1920***	-4.31
	after	1.8825	1.9566	-0.0741 (0.0673)	-1.18
Transport difficulty (y_6)	before	1.7893	1.8808	-0.0915***	-2.88
	after	1.7861	1.8034	-0.0173 (0.0561)	-0.36

Source: Author's calculation.
Note: ATT refers to the difference in the transaction costs between the ICT group and NICT group after matching; The values in the brackets are the standard error obtained by the bootstrap method, whose number of repeated samples is 500; ***, **, and * indicate the significance of 1%, 5%, and 10% respectively.

circulation network. So, it can be concluded that the use of ICT has little effect on enforcing costs of farmers.

The robustness of our results was checked by using alternative matching methods that account for similar potential biases that may arise when selecting estimation strategies (HOU et al., 2019). We use kernel matching, and caliper matching methods to verify the robustness of our matching which are shown in table 6. The results of average treatment effect in the two methods are consistent with that of the nearest neighbor matching method, which indicate that the present results are robust.

CONCLUSION

The study focuses on the impact of ICT on vegetable farmer's transaction costs of China. The PSM technique was employed to create a balanced sample of ICT users and nonusers, which enables us to eliminate self-selection bias arising from all kinds of covariates. The findings of the study revealed that the use of ICT reduced the information costs which leads to improve the accuracy of information and provide comfort for searching someone individual. The ICT usage also reduce the negotiation costs as well as reduce the negotiation time between farmers and buyers. Further, the impact of using ICT on the enforcing costs, education, household income per capita, market distance, labor, and to join a cooperative have positive impacts on the decision of vegetable farmers to adopt ICT.

Based on the results of the study many policy implications have emerged. The study concluded that using ICT can help reduce the information costs of vegetable farmers. Conversely, it is recommended to encourage local governments, industry associations, enterprises, and other organizations to popularize mobile phone and Internet education, stimulate farmers' awareness and ability to gather information and guide farmers to make full use of ICT. It is suggested to optimize the village information transmission mechanism. It is necessary to provide farmers timely and reliable agricultural information through mobile phones, the Internet and other channels which makes it important to play the active role of the information service organization, to boost farmers' enthusiasm for market participation and increase their income. The results of the study showed that the use of ICT can help reduce the negotiation costs of vegetable farmers. It is suggested to speed up the establishment of information sharing and communication platforms for vegetable suppliers and demanders in various regions, conduct

Table 6 - Robustness test results of PSM.

Variable	----------Kernel matching----------				----------Caliper matching----------			
	ICT	ICT	ATT	t	ICT	ICT	ATT	t
Search difficulty (y_1)	2.3276	2.4696	-0.1420**	-2.32	2.3269	2.4884	-0.1615**	-2.55
Information accuracy (y_2)	3.1368	2.9660	0.1708**	2.57	3.1412	2.9448	0.1964***	2.86
Negotiation time (y_3)	0.2164	0.3125	-0.0961**	-2.24	0.2172	0.3133	-0.0961**	-2.14
Contact frequency (y_4)	1.4884	1.2645	0.2239*	1.93	1.4922	1.2825	0.2097	1.63
Default risk (y_5)	1.8825	1.9677	-0.0852	-1.58	1.8859	1.9643	-0.0784	-1.41
Transport difficulty (y_6)	1.7861	1.8202	-0.0341	-0.89	1.7853	1.8247	-0.0394	-1.00

Source: Author's calculation.
Note: ***, **, and * indicate the significance of 1%, 5%, and 10% respectively.

real-name authentication to ensure the authenticity and reliability of traders' information, providing a good trading environment and negotiation channels for both parties on this basis, and even consultation and some other service. Besides, the electronic transaction mode should be promoted. The contract should be transferred from paper to electronic, to ensure the reasonable and legal transaction, safeguard the economic interests of both parties and ensure the fairness and justice of the transaction process. The government should continue to improve the market supervision system and strengthen infrastructure development, formulate effective market regulations, and intensify efforts to crack down on and punish illegal market activities like the malicious breach of contract, to better promote the structural adjustment of agriculture and the orderly circulation of agricultural products throughout the country. Besides, some subsidy policies can be added to encourage vegetable farmers to use mobile phones, the Internet, and other equipment, to gradually cultivate farmers' habits of using ICT and enable each household has access to optical fiber and internet as soon as possible, to better promote the modernization of China's agriculture.

Limitations of the study included the fact that our survey sample; although large, is limited to a cross-sectional data set. If panel data can be obtained in future research it will better reflect the impact of technological innovation on transaction costs. Furthermore; although, propensity score matching successfully solves the self-selection bias caused by observable factors, it is unable to address the potential bias arising from the unobservable. These problems are expected to be solved by future studies.

DECLARATION OF CONFLICT OF INTEREST

The authors declared that they have no conflicts of interest to this work.

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AUTHORS' CONTRIBUTIONS

Shijia Kang, Xiaomeng Jiao and Shaofeng Zheng conceived and performed the farm survey. Shaofeng Zheng supervised and provided data. Shijia Kang performed statistical analyses. Shijia Kang and Arif Ullah prepared the draft of the manuscript. All authors critically revised the manuscript and approved of the final version.

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