

Farmer's adoption tendency towards drought shock, risk-taking networks and modern irrigation technology: evidence from Zhangye, Gansu, PRC

Farmer's
adoption
tendency

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Abstract

Purpose – The purpose of this paper is to measure Farmer's adoption tendency towards drought shock, risk-taking networks and modern irrigation technology.

Design/methodology/approach – Based on this assumption, this paper evaluated the data gathered from 498 household surveys of Zhangye, Gansu province, PRC, by using the binary probit model. First, the empirical data was analyzed for evaluating the impact of drought shock and risk-taking tendencies on the adoption of modern irrigation technology by farmers. Second, the authors introduced informal risk-bearing networks with formal risks. Final, based on the empirical results, the sustainability test, along with the marginal effect analysis and the degree of impact was carried out.

Findings – The results show that the drought shock has a significantly deferent effect on the modern irrigation technology of the farmers. The probability of using technology for each level of drought loss is reduced by 15.02%. The risk-taking network has a significant role in promoting the modern irrigation technology of farmers. The probability of adoption for each additional unit of rural household labor security supply, the likelihood of adoption by farmers increased 23.11%, the probability of approval for each level of relative support, and neighborhood assistance by farmers increased by 13.11% and 17.88% respectively. This study further revealed that insurance purchases enabled farmers to adopt new irrigation technology with the probability increased by 24.99%; easily available bank loans increased the probability of farmers using

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irrigation technology by 31.89%. From the perspective of interactions between farmers, the risk-taking network can alleviate the inhibitory effect of drought impact towards the adoption of irrigation technology. Among the control variables, the number of years of education, the age of farming, the degree of arable land, the distance from home to the market, and the price of water all has significant effects on the adoption of modern irrigation technology by farmers.

Originality/value – The novelty of the study is that it illustrated the interactive influence of drought shock and risk-taking networks on the farmer's adoption tendencies of modern irrigation technologies, the inner relationship among drought impact, the risk-taking network and the farmer's adoption behavior and provide an interactive relationship between the formal risk-taking network and the non-risk-taking network in farmer's technology adoption.

Keywords Adoption of modern irrigation technology, Drought shock, Probit model, Risk-taking network

Paper type Research paper

1. Introduction

Drought and water shortage are the hard constraints that restrict the sustainable development of agriculture in northwestern China. It has shown that the practice of modern irrigation technologies has the potentiality to reduce drought risk by providing efficient use of water, which further reduces rural poverty and promotes the changes in agricultural sustainability (Koundouri *et al.*, 2006). In the arid and semi-arid regions of Northwest China, the promotion of modern irrigation technology and the development of water-efficiency of agricultural production are drawn extend strategic importance for ensuring water security in the region along with ensuring food security and environmental safety in China, moreover, promoting the sustainable development of the modern agriculture-based rural economy. Since 2003, the need for “developing irrigation technologies” was stated in 16 consecutive (China) central documents No. 1 and the central working conference on water management. In 2020, the central document No. 1 again stated the emergence of the efficient use of water in terms of agriculture irrigation, which further clearly prolonged with the policy “accelerating the development of efficient water-saving irrigation technology and realizing 100 million hectares of new and efficient farmland for saving water in irrigation.” In all extend, governments of all levels have also gradually increased the investment in modern irrigation technology and adopted various tactics, such as industrial subsidies and so on, to encourage farmers to adopt irrigation technology.

However, practically the multiple advantages of modern irrigation technology not only has a low penetration rate with a slow promotion process but also has held substantial heterogeneity in the adoption process of different farming technology, which severely hinders China's goal of achieving 50% of the high-efficiency level in water-saving technology by 2020. Thus, the elimination of hindrances and complications of the low adoption rate among farmers has some significant values, both theoretically and practically, for exploring the establishment of a long-term mechanism for promoting modern agricultural technology. The academic community has conducted extensive research on the adoption of modern irrigation technology by farmers. The existing literature mainly focuses on the factors affecting the adoption of advanced irrigation technologies by farmers, which generally based on the theory of planned behavior. This research reveals some substantial factors, which usually affects the adoption of advanced irrigation technologies by farmers such as biophysical factors, demographic characteristics of the family, the family economic resource conditions, market access and distribution services, social capital, credit restrictions and so on (Genius *et al.*, 2013; H. Wang *et al.*, 2013; Wossen *et al.*, 2015; Yamamura, 2013; Rui and Qian, 2017; Jieling *et al.*, 2018). However, on the basis of the literature review parts of this present article, it could be clearly found that the existing

works of literature pay less attention to the impact of natural disasters on the behavior of farmers for using modern irrigation technologies, as well as the risk-taking network is not considered before by any researcher within this impact process.

The design of this study focuses on four fundamental issues as follows: first, is drought shock and risk-taking networks have a significant impact on the adoption of modern irrigation technology by farmers? Second, are there any mitigating effects of the formal risk-taking network and the informal risk-taking network on the drought consequences that farmers face in implementing modern irrigation technologies? Third, in rural areas of northern China, when farmers face drought shocks, is it a formal or informal risk-taking network that plays a more significant role? Fourth, Can informal risk-taking networks consider as an effective alternative or complement to a formal risk-taking network?

The structure of this paper is as follows: Section 1 is the introduction, which provides the base structure of this study; Section 2 is the literature review and theoretical analysis, Section 3 is the econometric model and variable description, which mainly introducing the data source, model construction and related variables; Section 4 is the analysis of empirical results; Section 5 is the test for stability and the marginal effect analysis; and Section 6 is the conclusion and policy inspiration.

2. Literature review and theoretical analysis

The adoption of new technologies by farmers usually depends on the result of a careful compromise between risk minimization and profit maximization, as suggested by the framework of economic theory (Caswell and Zilberman, 1986). Agricultural production mostly depends on natural externalities, which usually led farmers to face many external constraints, such as risk from the natural disaster. A combined superposition with several risks will inevitably lead to an unfavorable agricultural outcome, which will create difficulties for farmers for adequate distribution capital, which further affects their behavior in production and investments.

Drought shocks are exogenous in nature and uncontrollable: they mainly create some constraints in which families of farmers suffer from a lack of water in agricultural production or their day to day life, and a shortage of water can hamper the living conditions of farmers (Mezamorales, 2010). The relationship between drought effects and modern irrigation technologies for farmers has not yet come to a common opinion. Most scientists believe that the impact of drought has a positive impact on the adoption of modern irrigation technologies. Carey and Zilberman (2002) used a stochastic dynamic model to study the impact of drought on the adoption of irrigation technology by farmers. The results show that the stronger the drought, the more farmers tend to apply modern irrigation technology. Also, some scholars believe that, while the ultimate goal of modern irrigation technology is to solve the drought problems that arise in the agricultural production of farmers and increase the capacity for drought resistance among highly vulnerable farmers, farmers with a high degree of vulnerability are usually risk-averse.

In contrast, Fufa and Hasan (2005) also showed that farmers could only sustain in the case of survival; the production risks brought by the adoption of new technologies will limit the promotion of new diversity in rural areas. Therefore, a common fact is that the farmer's adoption of modern irrigation technology is positively affected by the adverse effects of drought. As Ryan and Gross (1943) demonstrated the impact of social networks on the adoption of agricultural technology, the academic community began to focus on the risk-sharing mechanism of social networks in the adoption of farmer technology, namely, the informal risk-taking network. It can be defined as the social relationship network formed by farmers, to bear the economic risks of rural families by relying on family membership, kinship and geographical relationships (Fafchamps and Lund, 2003). Usually, farmers have limited communication and access to information; that is, why most

farmers are in an environment with incomplete information. As more farmers adopt new technologies, communication and the learning process of technology adoption can effectively improve farmers' knowledge accumulation, boost the utilization of efficient technological advancements and flourish the risk guarantee within the farmers adopting new technologies (Bandiera and Rasul, 2006).

Farmers can promote the active exchange and circulation of information, reduce information asymmetry and transaction costs through the use of mutual communication and learning within the informal risk-taking network, thus reducing market inefficiency and improving farmers' adoption of new technology. The external network of social relations can facilitate households via technical communication, reduce risks and uncertainties, and provide vital information for adopting agricultural technology (Conley and Udry, 2010). Matuschke and Qaim (2009) also demonstrated that farmer's adoption of new technologies vastly dependent on the social relationship network. Farmer's attitudes toward the adaptation of new technology are not fixed behavior; instead, it involves a dynamic learning process that follows the principles of the gradual transition model (Genius *et al.*, 2013).

The formal risk-taking is another vital core content in the social risk-taking network. It mainly based on formal institutional mechanisms provided by the government or the market for risk management, including agricultural insurance and financial market credit (Xiaoyong, 2007). Previous studies generally amplified on the basis that the commercial insurance market and financial market in rural areas are not sound, and its impact was minimal on the adoption of new technology by farmers (Alem and Broussard, 2018), the impact of the formal risk-taking network on technology adoption was neglecting. Therefore, the formal risk-taking network has significant motivational effects for the adoption of new technology. The existing literature and relevant reference showed that our current research holds significant theoretical value and provides a considerable research gap for this emerging research dimension.

Throughout this research, we have focused on the following two aspects: first, find out the existing effects of drought shock on the modern irrigation technology among farmers, less attention to the formal risk-taking network. Second, find out the motivating effects of risk-taking networks on farmers' behavior for the adoption of new technology, only focuses on the impact of informal risk-taking networks, ignoring the relationship between formal risk-taking networks and technology adoption.

3. Econometric model and variable description

3.1 Data sources

The data set we used in this paper derived from the field survey of farmers conducted by the research team in Zhangye city, Gansu province, China from October to November 2016. The survey was systematically designed for gathering the data from the specific geographical area, which represents the modern irrigation technology in Zhangye city, namely, Dangzhai town, Ershilipu town, Shangqin town, Shajing town, Mingyong town and Sanzha town. We set some fundamental aspects of choosing the research site, which meets with our research objectives, and those assumptions are as follows: first of all, the region is dry in nature and evaporation rate is also high, with an average annual precipitation of this region is only 210 mm, and the evaporation capacity is as high as 2,000 mm, there is a severe shortage of agricultural irrigation water, which is called the "typical resource-type water shortage zone." Second, the region located in China's high-efficiency water-saving irrigation demonstration zone. Over the years, within this region, modern irrigation technologies have been continuously promoted and tested with many advanced technologies. Third, the region mainly covered with dry farming grains such as wheat and corn, and the shortage of water resources here crossed a high level. It is an inevitable choice for this region to popularize

modern irrigation technology and develop water-saving in terms of agricultural production. Therefore, the selected sample area could have been considered as typical and representative within the context of our research objectives. The survey used stratified sampling and convenience sampling methods. For these six townships, first of all, we selected 3-5 villages with a large population and concentrated distribution in each township, and then randomly select 30-40 farmers in those villages. At last, in-depth interviews were conducted with the head of each household to obtain first-hand information. The contents of the field survey mainly include essential characteristics of the village, individual information and family characteristics, necessary pieces of information on agricultural production of farmers, utilization of water resources and adoption of modern irrigation technology, knowledge of modern irrigation technology used by farmers and risk behavior of farmers.

3.2 Sample characteristics

Table 1 represents the status of modern irrigation technology among the farmers of the sampling area. Table 1 shows that the farmers in Dangzhai and Ershierlipu town mainly use sub-membrane drip irrigation technology, and on the other hand, low-pressure tube irrigation technology mostly dominated in Sanxia, Shajing, Shangqin and Mingyong township.

Among them, the proportion of using sub-membrane drip irrigation technology for the Dangzhai town is 17.67%, and for Ershilipu town, the ratio was 3.01%. Overall sub-membrane drip irrigation adopting tendency was 27.91%. The proportions of low-pressure tube irrigation technology in Shangqin, Shajing, Mingyong and Sanxia town were 14.66, 13.45, 9.63 and 7.63%, respectively, and the overall adoption rate is satisfactory. In the low-pressure tube irrigation technology adoption zone, the adoption rate is 49.80%. Also, 4.02% of the farmers in Shangqin town adopted micro-sprinkler irrigation technology. From the overall analysis of the sample, the proportion of water-saving irrigation technology was 81.73% and available technology was 18.27%.

Table 2 represents the statistical representation of the characteristics of individual farmers and their families. According to the sample characteristics, among 498 households,

The sample area	The total number of households (%)	Low-pressure tube irrigation technology	Using technology		
			Sub membrane drip irrigation	Micro-sprinkler irrigation technology	Unused technology
Dangzhai town	135 (27.61%)	14 (2.81%)	88 (17.67%)	0 (0)	33 (6.63%)
Ershilipu town	28 (5.62%)	8 (1.61%)	15 (3.01%)	0 (0)	5 (1.00%)
Shangqin town	125 (25.10%)	73 (14.66%)	0 (0)	20 (4.02%)	32 (6.43%)
Shajing town	97 (19.48%)	67 (13.45%)	18 (3.61%)	0 (0)	12 (2.41%)
Mingyong town	75 (15.06%)	48 (9.63%)	18 (3.61%)	0 (0)	9 (1.81%)
Sanxia town	38 (7.63%)	38 (7.63%)	0 (0)	0 (0)	0 (0)
Total	498 (100%)	248 (49.80%)	139 (27.91%)	20 (4.02%)	91 (18.27%)

Table 1.
Adoption of modern
irrigation technology
of farmers

Note: The numbers in brackets are the proportion of samples to the total samples

Table 2.
Personal and family
characteristics of
households

Demographics			Demographics		
Gender	Number	Proportion (%)	Duration of the farming	Number	Proportion (%)
Male	273	54.82	Less than 20 years	81	16.27
Female	225	45.18	21-30 years	179	35.94
Age			31-40 years	134	26.91
Under the age of 30	15	3.01	41-50 years	85	17.07
31-40 years old	47	9.44	More than 50 years	19	3.82
41-50 years old	203	40.76	Planting area		
51-60 years old	132	26.51	Under 5 ha	61	12.25
More than 61 years old	101	20.28	5-15 ha	277	55.62
Duration of education			15-25 ha	109	21.88
0-6 years	242	48.59	More than 25 ha	51	10.24
7-9 years	178	35.74	Agricultural income		
More than 10 years	78	15.66	Less than ¥10, 000	111	22.29
Family size			¥10, 000-¥20, 000	108	21.69
2 the following	47	9.44	¥20, 000-¥30, 000	96	19.27
3-5 people	356	71.48	¥30, 000-¥40, 000	73	14.66
More than 6 people	95	19.08	More than ¥40, 000	110	22.09

male households accounted for 54.82% and women accounted for 45.18%. The minimum age of the respondents was 22 years old, the maximum was 78 years old and the majority of farmers are between 41 and 50 years old. The average duration of education in the rural household was six years, about 84.33% of the farmers had junior high school education or below, while 15.66% had a high school education or above. Nearly 72% of the sample households had a family size of 3-5 people. Among them, the average duration of farming was 32 years, and nearly 63% of them were between 21 and 40 years old. The average planting area of farmers is 14 ha, about 78% of farmers planting area, was 5-25 ha. The vast majority of rural households (56%) have an agricultural income of more than RMB 20,000.

3.3 Model construction

As “the adoption of modern irrigation technology by farmers” was used as the explanatory variable in this paper, it is a binary selection variable that can be substituted by 1 and 0. In a case of Pakistan, [Saqib et al. \(2016\)](#), and in a case of the Shandong province of China, N. [Wang et al. \(2016\)](#), used the probit model to study the impact of various socioeconomic factors on farmers’ technology adoption. [Rahman \(2008\)](#) used binary probit analysis to find out the adoption tendency of crop diversification in the case of Bangladeshi farmers. Similar approaches are also used by [Pfeiffer and Lin \(2014\)](#) and [Zhou et al. \(2008\)](#) for analyzing factors affecting Chinese farmers’ decisions to adopt a water-saving technology. Therefore, the binary selection model was used to examine the factors affecting modern irrigation technology used by farmers. The basic model sets as follows:

$$Y_i = X_i\beta + \varepsilon_i \tag{1}$$

Among them, the explanatory decision variables of the observation values are 1 and 0, the set of explanatory variables are relays on coefficients, which represent the parameters to be estimated, and random disturbance items are independent for each other. However, the specific form of the binary selection model determined by the probability distribution of the random interference term. When the term of random interference appears as a standard normal distribution, the binary probit selection model is adopted, when the term of random

interference seems like a logical distribution, the binary logic selection model is also adopted and when the random interference term exhibits an extreme value of “i-type” distribution, then the extreme value model is adopted. In the practical application of the binary selection model, random disturbance items rarely appear as an extreme “i-type” probability distribution, so binary extreme value selection model is rarely adopted, and the probit model and logit model commonly used. As the normal distribution is considered to be the natural and first choice of any distribution, the binary probit model adopted in this paper for measuring the estimation, which widely used in this present era. The specific form of the model demonstrated as:

$$pr\left(Y_i \geq 0 \mid X_i\right) = \ln\{P(Y=1)/[1-P(Y=1)]\} = \beta_0 + \sum \beta_i X_i + \varepsilon_i \quad (2)$$

After adding drought shock variables, the risk-taking network variables and related control variables, the research model used in this paper can be expressed as follows:

$$Y = \beta_0 + \beta_i shock + \sum_{i=1}^5 \gamma_i networks + \sum_{i=1}^9 \alpha_i X_i + \varepsilon_i \quad (3)$$

In Model 3, the shock represents the drought shock variable, networks represent the risk-taking network variable, the main effect reflects the drought shock effect and γ is the effect of risk-taking network. The coefficient represents the influence of the control variable. For testing whether the risk-taking network has the function to mitigate the drought shock, the interaction term between drought shock and the risk-taking network is introduced to establish the Model 4 for the empirical test, in terms of adopting modern irrigation technology among farmers. Which are given below:

$$Y = \beta_0 + \beta_i shock + \sum_{i=1}^5 \gamma_i networks + \sum_{i=1}^5 \lambda_i shock * networks_{i=1...5} + \sum_{i=1}^9 \alpha_i X_i + \varepsilon_i \quad (4)$$

Where the coefficient represents the influence on the interaction term of drought shock variable and risk-taking network variable, which leads that risk-taking network, can mitigate the inhibiting effect of drought shock on modern irrigation technology used by farmers.

3.4 Selection of indicators

3.4.1 Explained variables. The explanatory variable used in this paper is “whether farmers adopt modern irrigation technology or not,” which is a discrete binary variable. If farmers adopt modern irrigation technology, the value will be 1; otherwise, the value will be 0.

3.4.2 Core variables. The core variables of this paper are drought shock and risk-taking network.

3.4.2.1 Drought shock variable. Previous studies (Cavatassi *et al.*, 2011; Emerick *et al.*, 2016) have used indicators such as the drought experience of farmers and the frequency of drought occurrence to measure the drought shock. In this paper, the income loss caused by the impact of drought on agricultural production of farmers is selected to reflect the drought

shock. Specifically, this paper uses the proportion of the income loss caused by drought to the total income of farmers in the past five years to reflect the degree of drought shock.

3.4.2.2 Risk-taking network variables. The risk-taking network has two aspects, namely, social support and social relationship network (Heaney and Israel, 2008; Karlan *et al.*, 2009). Social support, namely, formal risk-taking network, which refers to the standardized risk-taking network and mechanism for making commitments to minimize the risks from the process of government and market participation. In this study, agricultural insurance purchase and bank loans selected as indirect variables of the formal risk-taking network.

Currently, the measurement of the informal risk-taking network based on the social network has not formed a unified standard. In previous studies, the number of friends and relatives, the relationship between friends and relatives, specialized loans, the communication between friends and relatives, gift expenditure and other indicators are mostly adapted to measure (Bandiera and Rasul, 2006; Ramirez, 2013). As farmers' own families are the most direct and weakest links in the risk-taking network, this paper adopts rural family labor security, kinship support and neighborhood assistance to measure the informal risk-taking network.

3.4.3 Control variables. Reference to existing research (Barham *et al.*, 2014; Genius *et al.*, 2013; Ward and Singh, 2015), the model introduces the following control variables: variables of farmers characteristic include age, gender and duration of education; family characteristic variables include farming years, family size and the degree of farmland fragmentation and land management scale; and village characteristic variables include the distance from home to market and price of water. Table 3 represents a detailed explanation of the main variables and descriptive statistics.

4. Empirical results analysis

In this paper, we used Stata 16.0 for excluding the multi-collinearity between the independent variables for each model and the binary probit regression model is used to analyze the survey data. Generally, the original data of the drought shock index and risk-taking network index were centralized before considering the interaction effect (Dawson, 2014). For avoiding multicollinearity, this paper adopts a stepwise regression method to investigate the impact of drought shock and risk-taking networks on the adoption of modern irrigation technology by farmers.

- first, the control variables are included in the model to establish the relation;
- second, indicators for measuring drought shock are included in the model, and then the model was established;
- third, the signs of formal and informal risk-bearing networks were incorporated into the model to develop the model; and
- final, the interaction between drought shock and the risk-taking network were introduced into the model and determine the model.

The model regression results are shown in Table 4.

It can be seen from the estimated results compiled in Table 4, that the significance level of chi-square test results for the likelihood ratio of the Model 1 is 0.0001, and the significance level of Models 2, 3 and 4 is 0.0000, indicating that the model passes 1% significance test with the introduction of new variables. At the same time, it can be seen that, along with the introduction of the core variable, the log-likelihood of each model and the absolute value of likelihood chi-square (χ^2) value gradually decreases. This indicates that the fitting of the model gradually increases, which further leads to an increase in Wald's χ^2 trend. The trend

				Farmer's adoption tendency	
Variable	Variable definition and description	Mean	SD		
<i>1. Explained variable</i>					
Farmers adopt modern irrigation technology	Whether farmers use modern irrigation techniques: 1 = yes; and 0 = no	0.572	0.463	439	
<i>2. Core explanatory variable</i>					
Degree of disaster loss	The proportion of income loss caused by drought caused by farmer households to total income (%)	0.417	0.395		
Family labor security	Family male labor force (person)	1.803	0.971		
Kinship support	The frequency with which families can get help from funds, in-kind, etc., from relatives: 1 = very few; 2 = less; 3 = general; 4 = more; and 5 = many	3.267	1.195		
Neighborhood assistance	The frequency with which the neighbors are willing to help when the family is in desperate need of help: 1 = never; 2 = occasionally; 3 = general; 4 = often; and 5 = frequent	3.926	0.847		
Agricultural insurance purchase	Whether the family purchased agricultural insurance: 0 = no; and 1 = yes	0.414	0.493		
Bank loan	Whether the family has obtained loans from financial institutions such as credit unions: 0 = no; and 1 = yes	0.669	0.471		
<i>3. Control variable</i>					
Gender	0 = female; and 1 = male	0.554	0.498	Table 3. The definition, valuation and descriptive statistics of variables	
Age	The actual age of the respondent (years)	51.54	10.28		
Years of education	Years of receiving a formal education (years)	6.317	3.880		
Years of farming	Years of agricultural production (years)	32.31	11.35		
Family size	Family population (person)	4.418	1.514		
Degree of arable land fragmentation	Number of cultivated land (block)	8.584	5.512		
Land management scale	Family planting area (mu)	14.38	11.32		
Distance from home to market	The distance between the farmer's family and the nearest market (in)	6.761	4.890		
Water price	The price of water in the village where the farmer is located is not high: 1 = not expensive; 2 = general; 3 = a little expensive; 4 = very expensive; and 5 = costly	3.550	1.220		

indicates that the model's explanatory power progressively increased after adding the drought shock variable, the risk-taking network variable and their interaction.

4.1 Drought shock and modern irrigation technology adoption by farmers

The regression results of the Models 2, 3 and 4 presented in Table 4 show that drought shock has a significant negative impact on the adoption of modern irrigation technology by farmers, indicating that the higher the level of income loss due to drought and the weaker the adoption of advanced irrigation technology by farmers. This paper believes that this may be caused by the long-term investment characteristics of advanced irrigation technology and the people's psychology for avoiding risks. The negative impact of drought weakens individual risk appetite, the leading farmer's tendency to invest in massive costs and full of uncertainty. Though the adoption of new technologies frequently faces the doubt of the farmers. Adopting a careful strategy is the best way to manage this production risk that arises from new technology adoption. This process of risk aversion is often used by farmers in developing countries who are trying to avoid risks in production (Mishra *et al.*, 2019).

Table 4.
Regression results of
probit model

Explanatory variables	Model 1	Model 2	Model 3	Model 4
Gender	0.1745 (1.5576)	0.1600 (1.4305)	0.1123 (0.9904)	0.1414 (1.2146)
Age	0.0138 (1.4216)	0.0097 (0.9324)	0.0139 (1.3315)	0.0086 (0.7632)
Years of education	0.0319** (2.0606)	0.0326** (2.0989)	0.0323** (2.0204)	0.0326** (2.0788)
Year of farming	-0.0235** (2.4706)	-0.0179* (1.8230)	-0.0196* (1.9598)	-0.0209** (2.2391)
Family size	0.0570 (1.4783)	0.0424 (1.1251)	0.0250 (0.6348)	0.0365 (0.9156)
Degree of arable land fragmentation	0.0238** (2.2367)	0.0222** (2.1049)	0.0191* (1.8238)	0.0186* (1.7046)
Land management scale	-0.0040 (0.9524)	-0.0035 (0.8535)	-0.0016 (0.4043)	-0.0010 (0.2522)
Distance from home to market	0.0177* (1.6606)	0.0199* (1.9119)	0.0193* (1.7052)	0.0199* (1.7760)
Water price	0.11167** (2.3946)	0.1082** (2.2819)	0.1005** (1.9892)	0.0922* (1.7969)
Drought shock		-0.1260*** (2.9130)	-0.1483*** (3.3516)	-0.1352*** (2.9659)
Family labor security			0.1730** (2.3977)	0.1614** (2.1866)
Kinship support			0.1244** (2.5738)	0.1280*** (2.6268)
Neighborhood assistance			0.1822** (2.5286)	0.1441** (1.9630)
purchase insurance			0.2570** (2.2561)	0.2648** (2.3132)
Bank loan			0.2382** (2.0561)	0.3148*** (2.6708)
Household labor security × drought damage				0.0672* (1.7849)
Relatives support × drought damage				0.1144** (2.1413)
Neighborhood assistance × drought damage				-0.0203 (0.3297)
Purchase insurance × drought damage				-0.1136** (2.0206)
Bank loan × drought damage				-0.0251 (0.4056)
Log-likelihood value	-417.0835	-416.6235	-392.7661	-381.2915
Wald's χ^2 test	36.16	37.21	80.94	103.31
p -value (prob > χ^2)	0.0001	0.0000	0.0000	0.0000
Pseudo R^2	0.0509	0.0905	0.1052	0.1314

Notes: *, ** and *** indicate the significance level of 10, 5 and 1 %, respectively, and the value in parentheses is the z-value

4.2 The risk-taking network and modern irrigation technology adoption of farmers

Table 4 shows that, among the risk-taking network variables, “family labor security” has a significant positive impact on the adoption of modern irrigation technology by farmers (Models 3 and 4). Because, in northwest China, agriculture has not been fully mechanized, and men are the main body of family risk-taking, as they are the main contributor within the family labor force. Therefore, the more affluent the male labor force, the stronger the risk-taking ability of the family and the more inclined it is to adopt modern irrigation techniques. “Kinship support” and “neighborhood assistance” has a significant positive impact on the adoption of modern irrigation technology by farmers, which indicates that the more frequent the network support from relatives and friends, the higher the enthusiasm of farmers to adopt modern irrigation technology. Because the more frequently farmers receive funds and materials from their relatives and friends, the more likely they are to abandon the use of technology because of a lack of funds. “Agricultural insurance purchase” and “bank loan” also have significant positive effects on the adoption of modern irrigation technology by farmers. This paper argues that the reason is that in the rural areas of China, where the formal insurance market is still not perfect, the farmers who purchase insurance have certain guarantees for the unknown risks arisen from technology adoption and which leads them to adopt modern irrigation technology.

4.3 The mitigation effect of the risk-taking network on drought shock

According to Model 4, the interaction terms of “family labor security,” “kinship support” and drought shock have a significant influence on the adoption of modern irrigation technology by farmers, and the interaction coefficient is positive, while the drought shock always has substantial influence and the coefficient is negative. Therefore, family labor security and kinship support have significant mitigating effects on the negative relationship between drought shock and modern irrigation technology. This shows that when the drought brings a significant degree of loss to farmers, but farmers can get support and help from the family’s male labor force and friends to cope with the drought shock, those farmers still have a strong ability to use the modern irrigation technology.

The interaction term of “neighborhood assistance” and drought shock has no significant impact on the adoption of modern irrigation technology by farmers, and the interaction term coefficient was negative. This indicated that neighborhood assistance had a certain alleviating effect on the negative relationship between drought shock and the adoption of modern irrigation technology by farmers, but in this term, the alleviating effect is not obvious. That is, mainly because droughts often spread over a wide range of areas and have a large disastrous effect. Once this happens, usually, the entire village will be affected. Neighbors have also been hit by adverse shocks, which denotes that they cannot provide enough assistance to help others for coping with the risks, so this kind of geographically confined mutuality may not be the main way of mitigating drought shocks. Nevertheless, the interaction item of “agricultural insurance purchase” and drought shock has a significant impact on the adoption of modern irrigation technology by farmers. That indicates the purchase of agricultural insurance has a significant mitigating effect and can lead to a negative relationship between drought shock and modern irrigation technology adopted by farmers. The interaction term of “bank loan” and drought shock has no significant interaction effect on the adoption of modern irrigation technology by farmers, and the interaction term coefficient was also negative. It shows that the farmers who get loans from banks and other financial institutions have a certain alleviating effect on the negative relationship between drought shock and modern irrigation technology, but the

alleviating effect was not obvious. That could happen mainly because the financial market is not sound in rural social areas.

4.4 Other variables and the use of modern irrigation technology by farmers

According to the regression results in [Table 4](#), the duration of education among farmers, the degree of farmland fragmentation, the distance from home to the nearest market and the water price all have significant positive effects on the adoption of modern irrigation technology by farmers. It indicates that the longer the education among farmers has, the stronger their willingness to adopt modern irrigation technology is. Which could mainly cause, because farmers with high education level provide them with the basic information, which usually assesses them with the opportunity to adopt and develop new technologies. The higher the degree of land fragmentation, the more farmers are willing to adopt modern irrigation technology. Although it is inconsistent with the empirical conclusion, it may be related to the fact that modern irrigation technology in this region is mainly sub-membrane drip technology. The higher the degree of farmland fragmentation, the more inclined farmers are to adopt drip technology, thus reducing investment in irrigation technology and equipment to improve the efficient utilization of water resources. The closer the distance from the home to market, the wider the channels for farmers to obtain agricultural technical information and the deeper their cognition and understanding of new technologies, thus increasing the adoption of irrigation technology. By considering the cost economy, the more expensive the water price and the more inclined farmers are to adopt modern irrigation technology for saving some of the costs. The years of farming have a significant negative impact on the use of modern irrigation technology by farmers, indicating that the long years of farming, the weaker the willingness of farmers to use irrigation technology, possibly because farmers with long farming are easily influenced by traditional concepts and they have certain rejection psychology to the use of new technology. Other control variables are not significant in terms of the present study.

5. Robustness test and marginal effect analysis

For testing the robustness of the empirical analysis model, this paper adopts the domestic and foreign works of literature to measure the drought shock and risk-taking networks, re-measure drought shock variables and risk-taking network variables and re-estimate the drought shock and risk-taking network to farmers. The impact effects of irrigation technology shown in [Table 5](#). The drought shock characterized by the problem of “family households suffering from drought in the past five years,” with values ranging from 1 to 5. The larger the value indicates, the deeper the frequency of drought; the informal risk-taking network in the risk-taking network adopts “the number of relatives and friends”; and the formal risk-taking network adopts the “amount of money farmers spent on commercial insurance in 2015.” Through data conversion, the variable that is not the default value is converted to 1, indicating that the farmer is involved in commercial insurance, while the default value is converted to 0, indicating that the farmer is not involved in commercial insurance. The estimated results in [Tables 5](#) and [4](#) are relatively consistent, indicating that the empirical analysis results in this paper are relatively robust.

As the information displayed by the binary probit model estimation coefficient is not comprehensive, only limited information can be given from the sign and significance of the coefficient. Therefore, for Model 3, we further calculated the marginal effects of each explanatory variable on the modern irrigation technology of farmers ([Table 6](#)). [Table 6](#) shows that for every level of drought shock, the probability of farmers adopting modern irrigation technology is reduced by 15.02%; in the informal risk-taking network for every 1

Explanatory variables	Model 5	Model 6	Model 7	Farmer's adoption tendency
Drought shock	−1.2550*** (2.7282)	−1.2120*** (2.6448)	−1.1643** (2.1841)	
Informal risk-taking network		0.0039** (2.1179)	0.0039** (2.3647)	
Formal risk-taking network		0.2638** (2.3629)	0.2545** (2.1989)	
Drought shock × informal risk-bearing network			0.1498** (2.3190)	
Drought shock × formal risk-bearing network			0.1630** (2.3958)	
Control variable	Have	Have	Have	
Log-likelihood value	−407.0429	−401.5010	−378.5458	
Wald's χ^2 test	51.16	64.06	68.58	
<i>p</i> -value (prob > χ^2)	0.0000	0.0000	0.0000	
Pseudo R^2	0.7027	0.8205	0.8464	

Notes: *, ** and *** indicate the significance level of 10, 5 and 1%, respectively, and the value in parentheses is the z-value – the estimation results of other control variables omitted here

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Table 5.
Test results of robustness for models

Explanatory variables	Coefficient	Standard error	z-value	<i>p</i> -value
Drought shock	−0.1502**	−3.3539	−2.45	0.014
Family labor security	0.2311***	3.4800	2.71	0.007
Kinship support	0.1311***	2.7016	2.40	0.017
Neighborhood assistance	0.1788**	2.4723	2.32	0.020
Formal insurance purchase	0.2499*	2.1808	1.92	0.055
Bank obtains loan	0.3189**	2.7133	2.23	0.026

Notes: *, ** and *** indicate the level of significance of 10, 5 and 1%, respectively, and the estimation results of other control variables omitted here

Table 6.
Marginal effect analysis

unit increase in family labor security supply, the likelihood of farmers adopting modern irrigation technology increases by 23.11%, and for every 1-grade increase in kin support and neighborhood assistance, the probability of farmers adopting modern irrigation technology increases by 13.11 and 17.88%, respectively. In the formal risk-taking network, farmers who purchase formal insurance will increase their probability of adopting modern irrigation technology by 24.99%, while farmers who obtain bank loans will increase their probability of adopting modern irrigation technology by 31.89%.

6. Conclusions and policy implications

This study contributes to a greater scientific understanding of the adoption drivers for new irrigation technology in the context of small-hold farming. The findings provided an opportunity to draw general lessons from the adoption scenario of the new technology by farmers: on why farmers adopt the new technology to reduce the risks from drought, and on the process, how different risk-sharing organization plays considerable effects as it was viable for the adoption process suggested by Aneani *et al.* (2012), Knowler and Bradshaw (2007) and Council (1996). This article presented recent advances examining the role of the adoption of modern irrigation technology by farmers toward drought shock and risk-taking

networks. It illustrates that technology adoption in agriculture is an engine applied economics perspectives and policy of economic growth, as well as it acts as an important way to increase farm productivity and improve food security around the world, which further assesses them to mitigate drought shock and proper utilization of risk-taking networks. Which is also supported by [Carey and Zilberman \(2002\)](#). However, the process of adoption is typically heterogeneous across farms and across regions, generating heterogeneous welfare effects ([Molle et al., 2008](#)). The main research conclusions of this study are as follows: first, the drought shock has a significant negative impact on the adoption of modern irrigation technology by farmers, which indicates that the drought shock will reduce the enthusiasm of farmers to adopt new technologies to a certain extent. This is also identical to the result of [Pandey et al. \(2000\)](#), [Cox and Fafchamps \(2007\)](#) and [Holden and Quiggin \(2017\)](#). Second, the risk-taking network has a significant positive impact on the adoption of modern irrigation technology by farmers, indicating that the adoption of advanced irrigation technology embedded in the risk-taking network and it has a significant role in promoting the adoption of new technologies used by farmers. [Alcon et al. \(2011\)](#) and [Carey and Zilberman \(2002\)](#) also support these findings.

Third, the risk-taking network has a specific mitigation effect on the drought shock. Among them, “family labor security supply,” “kinship support” and “purchase of insurance” all have significant mitigation effects on drought shock, while “neighborhood assistance” and “bank loans” have no noticeable effect on mitigating drought shocks. These findings also gain light with the findings of [Mishra et al. \(2019\)](#), [Upadhyay \(2004\)](#) and [Njuki et al. \(2014\)](#).

This conclusion indicates that the mitigating effect of family and kinship support as a “strong relationship” on drought shock is more obvious than the mitigation effect of neighborhood assistance as a “weak relationship” on drought shock. That determines the “strong relationship” based on the pre-existing family and kinship has a stronger impact on the modern irrigation technology of the farmers than on the “weak relationship” between the neighbors. This notion is also found by [Di Falco and Bulte \(2013\)](#) and [Audrey \(1990\)](#).

It can be seen that as an informal risk aversion mechanism, the social network has become the primary choice for farmers to face risk shocks although, the existing rural social security system, formal insurance market and structured finance are still not perfect. These findings also concluded by [Cremades et al. \(2015\)](#). At the same time, as a special form of social capital, the risk-taking network is regarded as an intangible asset or collateral under the adverse impact of drought impact. When farmers encounter drought impact, they can use formal or informal channels to obtain social help or relief resources, smooth household consumption and mitigate the impact of drought impact on farmers’ behavior. These observations are quite similar to the study of [Genius et al. \(2013\)](#), [Ullah et al. \(2015\)](#), [Abdulai et al. \(2011\)](#) and [Koundouri et al. \(2006\)](#).

Based on the above conclusion, it can conclude with some policy suggestions. Which are as follows: first, the government should provide full support to the social network, which influences informal networks such as social networks on risk-sharing, attach importance to the construction of a harmonious society in rural areas and encourage farmers to actively participate in village collective activities, thus broadening the farmer’s social network. Governments should play an active role in radiating the social network of a rural family. Second, while actively guiding the informal social network, the government and relevant departments should actively promote the formal risk-sharing mechanism, establish and improve the rural social security system and improve the risk response capacity of poor

farmers. Third, for upholding the increments of future production practice, the government should give priority to the popularization and demonstration of high-level modern irrigation technology used by other farmers. By using comprehensive promoting and implementing new technologies through the “demonstration effect,” more and more farmers will come forward to use the power of modern irrigation technology. Final, a comprehensive local policy must be integrated with the adaptation programs that are linked to livelihood development, which further can reduce the drought shock. As the resilience of drought, climate change has a big impact, which needs to be mainstreamed into local policies in the sense that it builds climate-resilient livelihoods and improves the adaptive capacity of farmers.

6.1 Theoretical contributions of this study

This paper is designed to measure the interactive influence of drought shock and risk-taking networks on the farmer's adoption tendencies of modern irrigation technologies. The inner relationship between drought impact, the risk-taking network and the farmer's adoption behavior of modern irrigation technology could be acted as supplementary research content for the behavior theory. Further, this paper discusses the interactive relationship between the formal risk-taking network and the non-risk-taking network in farmer's technology adoption, which could be helpful to expand the agricultural technology extension service path in China, and finally, provides theoretical and empirical support for the institutional innovation and policy optimization of agricultural technology extension in China.

6.2 Limitations and future scope of the study

First, this study is based on a small sample area of Zhangye city, Gansu province, but as China is a very big country so the following research should pay attention to expand the research area, increase the sample size and sample representation. Second, modern irrigation technology is a complex technology package composed of the dropper, sprinkler irrigation, flooding irrigation and other sub-technologies. As a result, respondents might have limited knowledge, which can influence some inconsistent information to explore the impact of drought, risk-taking networks in a deeper way. Thirdly, there is no doubt that the adoption cost is one of the main factors affecting the adoption of modern irrigation technology, so it might be a little bit difficult to adopt by poor farmers, which can be evaluated in the future. In this paper, potential measurement errors are considered and not included in the future aspects of a similar model. The empirical analysis should be covered sustainability and climate change issues, which could be a potential direction for future study as it holds a maximum interest among the growing amount of researchers, both locally and globally.

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