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Does External Shock Influence Farmer's Adoption of Modern Irrigation Technology?—A Case of Gansu Province, China

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Abstract: Due to the severe irrigational water scarcity and ever-growing contamination of existing water resources, the potential of improved and innovative irrigation technology has emerged. The risk-taking network may play an essential role in the adoption of modern irrigation technology (MIT). The main goals of the current study were to find the impacts of external shocks on MIT adoption by farmers. For doing so, the study analyzed the mediating effect of economic vulnerability (EV) and the moderating effect of the risk-taking network on farmer's adaptation of MIT. Economic vulnerability of farmers refers to risks caused by external shocks to the farming system which may affect the farmer's adoption of MIT. The empirical set-up of the study consists of micro survey data of 509 farmers from the Gansu Province of China. The results show that the external shock has a significant negative impact on adapting MIT by rural farmers. At the same time, EV plays an intermediary effect in increasing the impact of external irrigation on the adaptation of MIT. The intermediary to total effect is 36.57%. The risk-taking network has a moderate effect on the relationship between external shocks, affecting farmers to adopt MIT, while external shocks also increase EV which affects farmers' adopting MIT. Thus, it can be said that the risk-taking network regulates the direct path of external shocks affecting farmers' choice to adapt to MIT, and external shocks also affect farmer's MIT adaptation. The public and private partnerships should be strengthened to facilitate risk minimization. Government should provide subsidies, and financial organizations should also formulate more accessible loans and risk-sharing facilities. The government should expand the support for formal and informal risk-taking network. They should also extend their support for formal and informal risk-taking networks to improve the risk response-ability of vulnerable farmers. The concerned authorities should attach smallholder farmers' socio-economic structure and reform the existing policies according to their demands. The governmental authorities should also endorse the risk-sharing function of informal institutions.

Keywords: economic vulnerability; risk-taking network; sustainable water conservation; water scarcity; modern irrigation technology; capacity building

Citation: Tan, Y.; Sarkar, A.; Rahman, A.; Qian, L.; Hussain Memon, W.; Magzhan, Z. Does External Shock Influence Farmer's Adoption of Modern Irrigation Technology?—A Case of Gansu Province, China. *Land* **2021**, *10*, 882. https://doi.org/10.3390/land10080882

Academic Editors: Saskia Visser, Jan De Leeuw, Saskia Keesstra and Margot De Cleen

Received: 22 June 2021
Accepted: 16 August 2021
Published: 22 August 2021

1. Introduction

China has a severe water scarcity and possesses 28% of per-capita water among the global water share [1,2]. Lack of sufficient water resources creates enormous burdens for China [3,4]. Thus, promoting water-saving irrigation technologies has to be a great initiative to ensure improved food production, ecological and food security in arid areas of northwest China. Practicing and implementing MIT can improve the efficient use of water resources, reduce the risk of drought, and ultimately reduce rural poverty [5,6]. Since 2003, 17 consecutive No.1 documents of the Central Committee of the People's Republic of China have mentioned the need for "developing modern irrigation technology" [7]. In 2020, China's Central Document No. 1 focused on adapting high-efficiency water-saving irrigation in agriculture. It also highlighted the well-structured water-saving strategies to support large and medium-sized irrigation areas, improve resistance towards flood and drought, and building awareness regarding existing agricultural water-saving policies. The Chinese government and its associated organizations have also introduced different programs, services, and provided subsidies on procuring modern equipment for coping with the adverse effects of climate changes and global warming [8,9]. Despite having enormous advantages, modern technology was not widely adapted by farmers due to lack of proper information dissemination, biased coverage, and lack of technical knowledge [10,11]. Therefore, it is important to eliminate the constraints and obstacles of the low adoption rate of farmers for exploring the long-term implications of MIT.

In this way, farmers' decision-making behavior is essential, which may be influenced by different internal and external factors [12]. We focused on analyzing the external factors of the impact of policy and environmental conditions, technical attributes, infrastructure, and institutional strategies [13,14]. The most relevant influencing factors are demographic characteristics, economic endowment characteristics, differences in socioeconomic status, social learning, risk appetite, and inter-temporal selection [15–17], while external shocks are the main factors associated with adopting MIT [18].

As agriculture is a prime source of income, farmers frequently suffer from various external shocks such as natural disasters, prices, and demand [19], which further creates income instability for farmers. However, the uncertainty and instability of income endanger the non-economically vulnerable families to fall into economic vulnerability, making vulnerable families more vulnerable, or even permanently vulnerable [20]. If farmers could have handled these external shocks, they could have achieved a sustainable livelihood [21]. In these circumstances, most farmers tend to averse the risk; the degree of risk aversion is high, especially among economically vulnerable farmers. Even if the external shock does not emerge, in order to reduce the risk exposure and increase the preventive savings, the farmers usually give up the opportunity of high risk and high income and choose the low-income but relatively safe economic activities, such as not adopting or reducing the adoption of MIT [22,23]. This problematic situation raises the issue of "How to address the inhibition of external shock on farmers' technology adoption behavior?". Existing studies have proved that expanding the access to information and accumulating social capital is an effective way to encourage farmers to purchase agricultural insurance (risk-taking networks) [24,25]. Theoretically, the more developed the risk-taking network is, the more farmers can understand the role of new technology for profiling economic and ecological benefits [26,27]. The more farmers possessing the technical knowledge and experience, the more likely they can reduce the effects of various uncertainties in technology adoption and alleviate the inhibition of external impact on technology adoption [27,28]. However, relevant empirical studies are relatively rare. Economically vulnerable farmers are not entirely passive when encountering external shocks. In order to resist the negative impact of adverse shocks, farmers often rely on the risk-taking network to achieve risk coordination [29]. The risk-taking network has the role of effectively transmitting information, reducing impact damage, and relieving formal institutional constraints, including formal and informal risk-taking networks [30,31]. Formal risk-sharing network denotes to some proper institutional arrangements crafted by administration or market to avoid risks, including formal insurance, formal financial market credit, etc. [32]. Informal risk-taking network advances to the social network of rural households' economic risk-taking formed by their families, relatives, and geographical relationships [33].

Conversely, in rural areas of developing countries, the formal risk-taking network has several issues [29]. Fund recovery, risk aversion, formal insurance, and formal financial institutions often impose many restrictions on farmers. As a result, only a few farmers who meet the conditions can enter the capital market and insurance market, and the vast majority of farmers can only rely on the informal risk-taking network to realize the purpose of risk-sharing [34,35]. This notion can burden the ability of farmers to resist the external impact and reduce the risks and damage. Moreover, external shocks will increase the risk of agricultural investment. The vulnerable farmers with minimal resources can avoid the impact of the external impact with the help of the risk-taking networks. They will choose profitable production technology to improve family income, get rid of the economic vulnerability, and stay away from poverty. While the farmers who are unable to cope with the external impact fall into the poverty trap of low income and low risk [36,37]. This indicates that the risk-taking network may affect farmers' economic vulnerability through some mechanism and then affect the adoption of innovative technology. Throughout the existing research, it has been found that the local and international pieces of literature are concentrated within the theoretical and practical dimensions for assessing the relationship between farmers' technology adoption behaviors, external shocks, and their relationships from different perspectives, and have articulated a fruitful result [24,38–41]. These theories and methods have essential inspiration and reference significance for this study.

However, existing research also has some shortcomings. First, the existing research focuses on the direct impact of external shocks on farmers' technology adoption behavior, ignoring the mechanism and effect of economic vulnerability on farmers' technology adoption behavior. Second, the risk-taking network has an important impact on the production decision-making of farmers in deprived areas. However, there is insufficient attention to the risk-taking network in the research of technology adoption, especially in China, which has not been included in the vision of researchers. Third, the external shock, economic vulnerability, risk-taking network, and farmers' adoption of modern irrigation technology are not integrated into the same analytical framework to study the intermediary effect and regulatory effect of economic vulnerability and risk-taking network in farmers' adoption of modern irrigation technology. For fulfilling the above-mentioned research gaps, the study aims to explore the impacts of external shock for adopting MIT, propose a conceptual framework and test the framework statistically. Therefore, the study used a survey data of 509 farmers of the Gansu Province of China with ordinary least square method (OLS) to evaluate the impacts of external shock on farmers' MIT adoption. Moreover, the mediating effects of economic vulnerability and moderating effects of risk-taking network for triggering farmers' MIT adoption has been firmly analyzed. The study will be potentially impactful, as it evaluates the complex relationship among external shock, economic vulnerability, risk sharing network, and the adoption of MIT which is not previously fully captured by the existing literature. Moreover, it could be act as a theoretical and empirical base for promoting modern irrigation technologies and facilitating the smooth transition of adoption process. Interestingly, the statistically proven theoretical framework could be useful for future researches to explore each of the factors within specific modelling tactics.

2. Research Problem and Hypothesis

Farmers' production choice is a deliberate compromise involving minimizing risks and maximizing profitability [16,42]. The dispersion of production scale and technology shortcomings make farmers face several external limitations such as natural disasters directly. The external shock can increase farmers' economic vulnerability in agricultural production and their daily lives, inevitably leading to the uncertainty of agricultural income and allocating capital endowment efficiently.

Consequently, it can affect their production and investment behavior [43,44]. Modern irrigation technology is a capital-intensive technology with high investment risk and an extended return cycle. Farmers suffering from external shock often act slowly and take a specific waiting time for technology adoption. In this notion, careful adoption can avoid many uncertainties brought by new technology itself [45,46] and reduce adverse shock. On the other hand, small-scale farmers have a higher risk aversion tendency; moreover, they cannot bear the risk than large-scale farmers. The choice of family behavior must maximize the utility and weaken the uncertainty of various incomes as much as possible. Especially for high-economic vulnerability farmers, risk minimization is the "first principle" of their survival consideration. It could have been beneficial due to a decrease in technology adoption in comparison to psychological phenomenon of "pain" brought by "loss", which forces the mismatch between the expected marginal profit and the marginal cost of technology, distorts the optimal allocation of irrigation resources, and restricts the adoption and investment of modern irrigation technology by farmers [47,48]. Based on this, we propose Hypothesis 1 as:

Hypothesis 1 (H1): *External shock has a significant negative impact on farmers' adoption of MIT*.

Economic vulnerability reflects the possibility of farmers falling into poverty in the future. That is to say, as long as the probability of farmers' poverty in the future exceeds the established poverty line, the farmers are more vulnerable [49,50]. This definition dynamically reflects the trend of poverty in the future and has certain foresight [51,52]. The decline of family living standards caused by external shock will deepen the degree of farmers' economic vulnerability [53,54]. While external shocks directly impact farmers' adoption of modern irrigation technologies, they also affect economic vulnerability by changing household welfare levels and reducing farmers' ability to withstand external shocks, indirectly affecting farmers' modern irrigation technology adoption. On the one hand, external shocks affect economic vulnerability by changing farmers' production behavior and consumption level.

The external shock will have a more significant effect on agricultural production activities, destroy the livelihood assets of farmers, and damage the human capital of families and weaken their income-generating ability [55,56]. All of the facilities mentioned above welfare level of farmers to decline or the consumption expenditure to increase, increasing the economic vulnerability, especially when some very economically vulnerable farmers are subject to a substantial external impact, which will make them fall into a vicious circle of "low investment capacity-increased economic vulnerability low-investment capacity" [57]. This finally led to a reduced ability for the farmers to invest for modern irrigation technology with high investment capital and reduced adoption tendency. Second, external shocks affect farmers' economic vulnerability by reducing their risk response level [58,59]. For non-vulnerable farmers, even if the shock makes them fall into vulnerable groups, they can quickly reduce their economic vulnerability by relying on their ability. However, the vulnerable farmers themselves cannot bear risks and do not have the means to resist risks. The external shock will further weaken their ability to bear the negative shock and deepen the degree of economic vulnerability [60,61]. Moreover, the vulnerable farmer cannot enter the capital and insurance market for "self-insurance", which restrict their ability to bear the initial investments of new technology, thus showing a lower tendency of modern irrigation technology adoption. The study proposes Hypothesis 2 as:

Hypothesis 2 (H2): *There is an intermediary effect in the external shock on the adoption of MIT*.

The risk-taking network plays a crucial role in risk-sharing in farmers' adoption of new technology. In imperfect formal risk-taking networks, informal risk-taking networks, namely social networks, is mainly used to resolve and share the impact of external shocks [14,62]. China is a country with prominent relationship network characteristics. When farmers suffer from external shock in the process of new technology adoption, relatives and friends in the informal risk-taking network provide experience, technology, and financial assistance for their agricultural production and other activities, minimize negative impact, and encourage farmers to adopt high-income and high-risk technology [28,63]. At the beginning of introducing agricultural technology, its characteristics are not "transparent" to all users [64,65]. Farmers exchange and learn from many adopters in the informal risk-taking network, gradually revise their evaluation of new technology, effectively reduce the uncertainty of potential benefits, and speed up the process of technology adoption [44,66]. Narayan and Pritchett [67] found that informal risk-taking networks based on clan networks and village trust can reduce transaction costs and disperse external impact on farmers, thus promoting the extension of agricultural technology and the transmission of technical information. Ward and Pede [68] found that an informal risk-taking network has the function of alleviating external shock in farmers' adoption of modern irrigation technology. Theoretically, the denser the informal risk-taking network, the more likely the family is to form a risk-sharing network and to effectively deal with the various risks in production and life at any time [69,70]. Based on this, the paper proposes Hypothesis 3 as:

Hypothesis 3 (H3): *There is a moderating effect of the risk-taking network in the impact of external shocks on Farmers' adoption of MIT*.

The risk-sharing mechanism regulates the impact of external shocks on the economic vulnerability of farmers. Based on kinship support, the informal risk-taking network can improve the ability of farmers to resist external shocks by increasing their current income, promoting private lending, and expanding employment opportunities [23,71]. Families with weak economic vulnerability and more considerable informal risk-taking network resources are more likely to choose income diversification to maintain the smooth consumption level of families [72,73] and reduce the incidence of poverty. According to Mobarak and Rosenzweig [74], informal risk-taking networks can indirectly reduce economic vulnerability by improving the ability to access information, funds, emotional support and enhance the ability of families to resist adverse shocks. Foster and Rosenzweig [63] found that farmers can negatively impact physical objects, loans, and other decentralized family members through the informal risk-taking network. Which of these can reduce the degree of risk exposure, improve the risk-taking capacity of farmers and mitigate the negative shock of risk events, ultimately increase family income, and indirectly reduce economic vulnerability? Based on this, the paper proposes Hypothesis 4 as:

Hypothesis 4 (H4): *The risk-taking network has a moderating effect on the relationship between external shocks and the economic vulnerability of farmers*.

The risk-taking network regulates the effect of economic vulnerability on farmers' adoption of new technology, directly reducing farmers' economic vulnerability [75,76]. The social relationship within the risk-taking network has the characteristics of high convergence and high tightness. The mutual support and fund transfer among the internal members make the informal risk-taking network function as formal insurance [77,78]. The larger the risk-taking network scale is, the more social resources and solutions are obtained in the face of uncertainty, the higher the risk response level, and the lower the economic vulnerability [79,80]. In this case, the more risk tolerance of farmers, the more willing to adopt irreversible investment technology and improve technology adoption. Based on this assumption, this paper proposes Hypothesis 5 as:

Hypothesis 5 (H5): *The risk-taking network has a moderating effect on the relationship between economic vulnerability and farmers' adoption of MIT*.

As per the above discussion, the article constructs a theoretical model of the relationship among external shocks, economic vulnerability, risk-taking network, and farmers' adoption behavior of MIT, as shown in Figure 1.

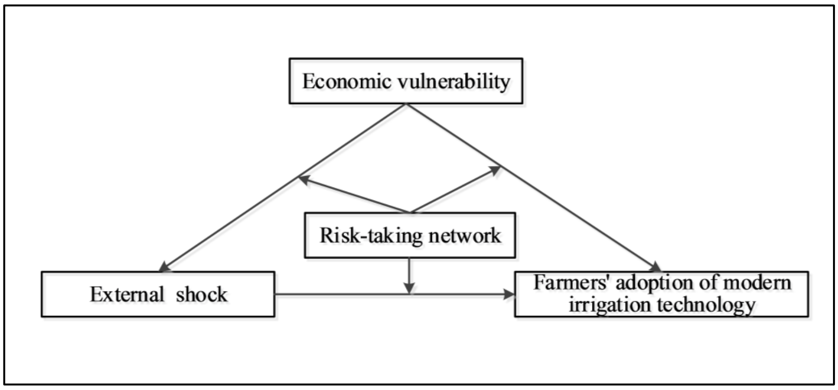

Figure 1. Theoretical model of the study.

3. Materials and Methods

The study used STATA version 16.0 to estimate the model coefficients using the ordinary least square method (OLS) after excluding the correlation between the variables in each model and considering the proportion of the follow-up intermediary effect.

3.1. Data Sources

The data set of the article was extracted from a survey based on the adoption of MIT by farmers within Northwest China. The survey was conducted in Gansu Province, China, from October to November 2019. The reasons for choosing Gansu Province as the research area were as follows:

First, geographically, Gansu Province is located in dry and fewer rainfall areas and a 264 high evaporation rate where average annual precipitation is only 210 mm of rain and the evaporation is as high as 2000 mm. These regions face an enormous shortage of water for agriculture, which is known as the typical resource-based water shortage area of "no irrigation, no agriculture". Second, Zhangye City is a typical national level high-efficiency water-saving irrigation demonstration area, which has continuously experimented and promoted MIT for 30 years with various types of irrigation technology. Thirdly, Zhangye City is a poverty-stricken area of "flower arrangement type" determined by the provincial party committee and the provincial government. Therefore, the data obtained from Zhangye City, Gansu Province, China, as a research site have a high research value. This survey adopts the method of combining stratified sampling and typical sampling. The sample population is divided into various subgroups such as age, gender, ethnicity, and educational level, the combination of the two-sampling method can provide more robust outcomes, as suggested by Etikan and Bala [81]. First, two sample counties (districts) are selected, namely Zhangye City and Wuwei city. Second, three towns with better irrigation infrastructure are selected in each sampled county (District), six towns. Thirdly, three native villages with a high population and focused dissemination are selected in each township, forming a total of 18 sample villages, and then randomly select 30 farmers from the villages to form 540 samples of farmers, and finally conduct in-depth interviews with each family to obtain fundamental understanding of the demographic characteristics. After an in-depth discussion with household, interviewers fill the questionnaire, all of whom are trained graduate students. A structured questionnaire has been designed to collect the data and for the better interpretation we have divided it into six important sections. The first section was dedicated to essential socio demographic information of the respondent such as age, gender, educational level, family size, land scale, position of nearest market along with extend of subsidies, and availability of credit. Moreover, the information reading social capital also extracted by means of social network, trust, prestige, and social participations. Section two denoted with the information fostering the production and irrigation mode. Section four, comprised with the variables of water resources utilization and adoption of water-saving technologies by covering scarcity perception, MIT awareness, associated uncertainty. Section five has been comprised by highlighting the governmental supports and promotional impacts of water-saving irrigation technology. Finally, section six dedicated to grasp the information regarding external risk- and risk-taking networks. A 5-point Likert scale was employed to take the ratings from the respondent. On the other hand, the questionnaire was designed and finalized after a pilot test with five farmers, and necessary modifications were implemented so that the farmer's response would be more precise. Finally, a total of 540 questionnaires were disseminated, whereas 509 reliable questionnaires were obtained by eliminating the missing vital information or filling in the questionnaire with apparent errors, with a 94% response rate. The team of interviewer paid a frequent visit to the sampling area and there was a gift voucher of CNY 12 (USD 1.86) for the interviewee, which could be a main reason for such a high response rate.

3.2. Measurement Model

The econometric models selected in this paper are the intermediary effect model and the regulatory effect model, which are described as follows:

3.2.1. Mediation Effect Model

Referring to the new intermediate efficiency test process proposed by Biesanz et al. [82] and Zhonglin and Baojuan [83], the regression models of the independent variable to dependent variable, independent variable to intermediate variable, independent variable, and intermediate variable to dependent variable are established by adopting the hierarchical regression method, respectively, as follows:

$$TA = c_0 + c_1 RS + c_2 X + \mu_1 \tag{1}$$

$$FV = \beta_0 + \beta_1 RS + \beta_2 X + \mu_2 \tag{2}$$

$$TA = c'_0 + c'_1 RS + c'_2 FV + c'_3 X + \mu_3 \tag{3}$$

Among them, TA represents the adoption degree of modern irrigation technology, RS represents external shock, FV represents economic vulnerability, X_i represents all control variables, μ_i represents random disturbance term, and C_i, β_i, C'_i represents the model regression coefficient. The specific test process is as follows: the first step is to verify the coefficient c_1 of Equation (1) $RS \to TA$ if it is significant, it is the intermediary effect theory, otherwise; the second step is to verify whether the coefficient β_1 in Equation (2) $RS \to FV$ and the coefficient c'_2 in Equation (3) $RC \to TA$ are significant. If they are significant, there is an intermediary effect. Skip to the fourth step, otherwise proceed to the third step; In the third step, the bootstrap method is used to test the original hypothesis directly H_0: $\beta_1 c'_2 = 0$. If it is established, the fourth step shall be continued; otherwise, the inspection shall be terminated. The fourth step is to verify the direct effect c'_1 in Equation (3) $RS \to TA$. if it is not significant, it means that economic vulnerability has only a complete intermediary effect. If it is significant, the fifth step is to carry out. The fifth step is to compare the symbols of $\beta_1 c'_2$ and c_1. If they are the same sign, then the economic vulnerability has a partial intermediary effect, and the proportion of intermediary effect is $\beta_1 c'_2 / c_1$.

3.2.2. Moderation Effect Model

According to Wen Zhonglin's [83], when the independent variable is a continuous variable and the regulating variable is a continuous variable or a category variable, a stepwise regression analysis is conducted to test the regulation effect. External shocks of independent variables, economic fragility of intermediary variables, and risk-taking networks of moderator variables are all continuous variables. Therefore, hierarchical regression analysis can be used when testing the role of the risk-taking network on the direct path or the path before and after the intermediary process. The theoretical model that correctly verifies the regulatory effect of the risk-taking network is as follows:

$$TA = b_0 + b_1 RS + b_2 SC + b_3 IP + b_4 RS * SC + b_5 RS * IP + b_6 X + \mu_4 \tag{4}$$

$$FV = d_0 + d_1 RS + d_2 SC + d_3 IP + d_4 RS * SC + d_5 RS * IP + d_6 X + \mu_5 \quad (5)$$

$$TA = z_0 + z_1 FV + z_2 SC + z_3 IP + z_4 FV * SC + z_5 FV * IP + z_6 X + \mu_6 \quad (6)$$

Equations (4)–(6) are the theoretical models of the direct path and the first half path, and the second half path of the intermediary process that influences external shocks affecting farmers' adoption of modern irrigation technology. Test the coefficients b_4 and b_5 of $RS * SC \rightarrow TA$ and $RS * IP \rightarrow TA$ in Equation (4), the coefficients d_4 and d_5 of $RS * SC \rightarrow FV$ and $RS * IP \rightarrow FV$ in Equation (5) and the coefficients z_4 and z_5 of $FV * SC \rightarrow TA$ and $FV * IP \rightarrow TA$ of Equation (6). If the interaction terms are significant, then the risk-taking network has a regulatory effect on each path.

4. Results and Discussion

4.1. Test and Analysis of Mediation Effect

From Tables 1 and 2, it can be seen that the fitness (R2) of each model passed the test at the significance level of 1%, indicating that the model assured viability and the application of the model is reasonable.

Table 2 represents the test results of the intermediary effect of economic vulnerability, as stated in the model (1–3). While, Table A1 denotes the data is reliable and valid (please see Appendix A). According to the intermediary effect test procedure, first, we test whether the external shock significantly impacts Farmers' adoption of modern irrigation technology. From model (1) (RS→TA), it can be seen that the external shock has a significant negative impact on the modern irrigation technology adoption by farmers, and the regression coefficient is −0.0762, which indicates that the external shock will inhibit the modern irrigation technology adoption by farmers. The results are parallel with Koundouri et al. [66] and Alcon et al. [5]. So, based on this assumption, hypothesis one (H1) is verified. This may be caused by modern irrigation technology's unique long-term investment characteristics and people's risk aversion psychology. The external shock weakens the individual's risk preference, resulting in farmers' doubts about adopting new technology with high investment costs and full of uncertainty. MIT's careful adoption is the best behavior to reduce risk exposure and the best choice to avoid external shock. The conclusion is consistent with Ghadim et al. [18] and Wang et al. [14]. In a study of rural Ethiopia, Gebremariam and Tesfaye [84], and Chilian small scale agroproducers, Salazar and Rand [85] confirmed the similar assumptions.

Second, we test whether the external shock has a significant impact on the economic vulnerability of farmers. The estimation results of model (2) (RS → FV) show that the external shocks have a significant positive impact on farmers' economic vulnerability, and the regression coefficient is 0.0813, indicating that the external shocks will aggravate the economic vulnerability of farmers. The external shocks make the farmers face more uncertainty, instability and eventually reduce the ability to bear the negative impacts and make economic vulnerability deeper for farmers [20,86]. Salazar and Rand [85] also revield similar results in a study of Nepalese pump irrigation system adoptions.

Finally, we test whether the intermediary effect of economic vulnerability is tenable. According to model (3) (RS→FV→TA), after introducing economic vulnerability, the external shock still has a significant negative impact on modern irrigation technology adoption by farmers. The economic vulnerability of farmers also has a significant negative impact on modern irrigation technology adoption. In a study of Jodhpur district of Rajasthan [87] outlined parallel outcomes. The regression coefficient is −0.3428, indicating that economic vulnerability will inhibit the adoption of modern irrigation technology by farmers. High economic vulnerability farmers have typical characteristics of low investment ability. In the face of high cost in the early stage of adoption of modern irrigation technology, vulnerable households are almost unable to invest, and finally, reduce the adoption degree or give up the adoption, which is consistent with the research of [52,88].

The combined results of model (1) and model (2) shows that economic vulnerability has a partial intermediary effect in the impact of external shocks on the adoption of modern irrigation technology by farmers, and the proportion of intermediary effect is 36.57%, which indicates that 36.57% of the impact of external shocks on the adoption of modern irrigation technology by farmers comes from economic vulnerability. At the same time, the fitness (R2) of the model increased from 0.2114 to 0.2856, which shows that the introduction of the economic vulnerability of intermediary variables significantly improves the explanation of the model for the adoption rate of modern irrigation technology of farmers. Therefore, H2 is assumed to be verified.

Table 1. Testing and estimation of the mediation effect of economic vulnerability.

Variable	Explained Variable		
	Degree of Technology Adoption (1)	**Economic Vulnerability (2)**	**Degree of Technology Adoption (3)**
External shocks	−0.0762 *** (0.0210)	0.0813 ** (0.0362)	−0.0727 *** (0.0210)
Economic vulnerability			−0.3428 ** (0.1648)
Gender	0.1311 *** (0.0443)	−0.0529 *** (0.0092)	0.1119 *** (0.0420)
Years of Education	0.0171 *** (0.0061)	−0.0018 (0.0013)	0.0103 * (0.0055)
Family size	0.0135 (0.0133)	0.0332 *** (0.0028)	0.0050 (0.0141)
Land scale	0.0031 (0.0023)	−0.0025 *** (0.0005)	0.0042 * (0.0023)
The proportion of agricultural income	0.2855 ** (0.1105)	0.0138 (0.0230)	0.2684 ** (0.1105)
Government subsidy	0.0493 (0.0461)	−0.0110 (0.0095)	0.0502 (0.0460)
Availability of credit	0.1364 *** (0.0503)	−0.0109 (0.0105)	0.1476 *** (0.0503)
Distance from home to the nearest market	0.0036 (0.0046)	−0.0015 (0.0010)	0.0038 (0.0046)
Intercept term	−0.2642 (0.1859)	0.4809 *** (0.0387)	0.1809 (0.1677)
F	10.01 ***	25.42 ***	14.15 ***
R2	0.2114	0.3379	0.2856

Note: ***, **, * indicate significant differences at 0.01, 0.05, and 0.10 levels, respectively; the figures in brackets are standard errors.

Table 2. Regression results of the moderator effect of risk-taking network.

Variable	Explained Variable		
	Degree of Technology Adoption (4)	**Economic Vulnerability (5)**	**Degree of Technology Adoption (6)**
External shocks	−0.1385 *** (0.0410)	0.0075 ** (0.0036)	
Economic vulnerability	-	-	−0.3426 ** (0.1551)
Social capital	0.0942 ** (0.0377)	−0.0151 * (0.0079)	0.2850 *** (0.1020)
Formal insurance	0.1061 ** (0.0453)	−0.0193 ** (0.0097)	0.0986 ** (0.0452)
External shock * social capital	0.0502 ** (0.0254)	−0.0124 *** (0.0046)	-
External shock * formal insurance	0.1038 ** (0.0459)	−0.0110 * (0.0067)	-
Economic vulnerability * social capital	-	-	0.4919 *** (0.1826)
Economic vulnerability * formal insurance			0.1349 ** (0.0643)
Gender	0.0890 ** (0.0416)	−0.0474 *** (0.0090)	0.0934 ** (0.0429)
Years of Education	0.0124 ** (0.0054)	−0.0039 *** (0.0011)	0.0106 * (0.0055)
Family size	0.0154 (0.0132)	−0.0333 *** (0.0028)	0.0161 (0.0143)
Land scale	0.0030 (0.0023)	−0.0026 *** (0.0005)	0.0031 (0.0023)
The proportion of agricultural income	0.3067 *** (0.1096)	0.0230 (0.0236)	0.2809 ** (0.1101)
Government subsidy	0.0835 * (0.0455)	−0.0131 (0.0098)	0.0729 (0.0456)
Availability of credit	0.0985 * (0.0508)	−0.0076(0.0108)	0.1111 ** (0.0508)
Distance from home to the nearest market	0.0020 (0.0046)	−0.0023 ** (0.0010)	0.0019 (0.0046)
Intercept term	−0.3678 ** (0.1855)	0.4836 *** (0.0390)	−0.4537 ** (0.2048)
F	9.45 ***	19.26 ***	16.24 ***
R2	0.1752	0.3359	0.2394

Note: ***, **, * indicate significant differences at 0.01, 0.05, and 0.10 levels, respectively; the figures in brackets are standard errors.

4.2. Analysis of Moderator Effect

Table 2 indicates the regulatory effect of the risk-taking network (model 4–6). In contrast, model (4) examines the regulatory effect of the risk-taking network on adopting modern irrigation technology as a direct path. The results show that social capital, formal insurance, the interaction between social capital and external shocks, and interaction between formal insurance and external shocks all significantly impact the adoption rate of modern irrigation technology of farmers. It also shows that the risk-taking network has a specific regulatory effect on farmers to mitigate external shocks towards adopting MIT. So, it can be assumed that the risk-taking network can alleviate the inhibition effect of external shocks on farmers' technology adoption to a certain extent. This is consistent with the conclusions of Yang [88] and Bandiera and Rasul [89], assuming that Hypothesis 3 (H3) is verified.

Model (5) tests the regulatory effect of the risk-taking network as per the economic vulnerability intermediary process within the first half. The results show that social capital, formal insurance, the interaction between social capital and external shocks, and interaction between formal insurance and external shocks all have significant adverse effects on farmers' economic vulnerability. They indicate that a risk-taking network plays a regulatory role in the relationship between external shocks and farmers' economic vulnerability. As an "invisible asset" of farmers, the risk-sharing mechanism can effectively play the role of smoothing consumption, reducing farmers' economic vulnerability, and improving the risk response-ability of farmers towards negative impact, which is consistent with the research conclusions of Breza and Chandrasekhar [90,91]. So, Hypothesis 4 (H4) is verified.

Model (6) tests the moderating effect of the risk-taking network on the second half of the economic vulnerability intermediary process. The results show that social capital, formal insurance, the interaction between social capital and economic vulnerability, and interaction between formal insurance and economic vulnerability have significant positive effects on modern irrigation technology adoption of farmers. This indicates that the risk-taking network plays a regulatory role in the relationship between economic vulnerability and the adoption of modern irrigation technology of farmers. There is a specific moderating effect: the risk-taking network will alleviate the inhibition of economic vulnerability on Farmers' technology adoption to a certain extent, supported by Morrow and Vennam [80], which indicates that Hypothesis 5 (H5) is verified.

It can be seen from Tables 1 and 2 that among the control variables, gender, years of education, the proportion of agricultural income, and credit availability have a substantial influence on the embracing of MIT by farmers. Compared with women, men are more aware of the benefits of modern irrigation technology with labor-saving attributes and are more inclined to adopt it. The higher education level of farmers possessed a more vital ability to master new technology is, and they are more aware of the importance of modern irrigation technology, and their willingness to adopt it is high. Farmers with higher agricultural income are more dependent on agricultural production and have a great demand for modern irrigation technology; therefore, the adoption degree is high. Modern irrigation technology is typically more capital intensive. Throughout the adoption process, it needs a lot of capital investment. In summary, the more easily accessible credit, the more adequate the adoption cost, and the stronger the adoption tendency. While, Tables A2 and A3 denotes the results of mediation and moderator effects are reliable and valid (please see Appendix B).

5. Conclusions

The study utilized a data set of 509 farmers from Gansu province of China for measuring the intermediary and regulatory effect model to reveal the correlation mechanism among external impact, economic vulnerability, risk-taking network, and the adoption of MIT by farmers. The major contribution of this research by adopting the model of intermediary effect and regulatory effect is to provide empirical evidence to make a database for future policy framework. The results portrayed that the external risk has a substantial adverse impact on modern irrigation technology adoption and economic vulnerability is part of the intermediary effect on the external impact. Moreover, the study revealed that the risk-sharing network has moderate impacts on external shocks and farmers' modern irrigation technology adoption. The analysis showed that external shocks affect the farmers' economic vulnerability and economic vulnerability affecting farmers' modern irrigation technology adoption. The results implied that the risk-taking network regulates the direct path of external shocks for affecting farmer's adoption of modern irrigation technology and regulates the first half and the second half of the intermediary process of external shocks through economic vulnerability.

Based on the above conclusions, to foster the adoption practice of modern agricultural technology and progress the risk-sharing ability of farmers, the following policy recommendations are put forward: (1) reducing the external impact of production is the key to promoting modern irrigation technology. The government should establish a price difference insurance system that can reduce the external risks in agricultural production. (2) In poverty alleviation through science and technology, the governments should pay attention to the popularisation of science and technology and focus on the risk management ability of vulnerable families. According to their risk attitude and tolerance, they should formulate targeted policies. (3) Expanding the scope of policy and agricultural insurance can enhance the regional communal security structure as it plays a leading role as official risk-taking networks, and improve the risk response-ability of vulnerable farmers. And (4) attaching cultural collaboration can inspire smallholders to join collective agricultural accomplishments, and broaden farmers' social relationship network. The governmental authorities should also endorse the risk-sharing function of informal institutions.

There are some limitations to this study. First, the paper is based on Zhangye City, Gansu Province, China, but whether it can reach the same conclusion in China or other countries and regions must be verified. Second, modern irrigation technology is a complex phenomenon with multiple categories, such as dropper, sprinkler irrigation, and flood irrigation. However, this paper only studied whether farmers adopt modern irrigation technology on an integrated basis. In further research, specific subcategories of MIT should be included within the analytical framework to explore the deep-seated role of external shocks, economic vulnerability, and risk-taking networks. Third, it is apparent that the acquisition expense is among the key variables that influence the behavioral intention of adopting MIT, however by considering the potential measurement errors, the study does not include them in the model. Whether this will affect the estimation results remains to be verified. The current study mainly focused on small regions where water scarecity is severe, therefore the farmers of the regions typically tended to adopt improved modern irrigation technology. Therefore, future researches should focus on wide geographic regions in order to extract more robust findings. The study pointed some key factors of social capital such as social network, trust, prestige, and social participations, however, if future researches could foster those factors within an integrated framework it could be more interesting. More specifically the future research can use the theory of planned behavior to explore whether the mentioned factors can trigger the perceptions of farmers. Finally, the potential studies can also use the tactics of structural equational modelling that evaluates the used theoretical model by means of multivariate analysis. The empirical models used in the present study also may adoptable for the areas where agricultural farming faces an unceasing threat from climate change, natural hazards, environmental degradation, and a lacking/inappropriate crop insurance policy that causes the food to be insecure in that area.

Author Contributions: Conceptualization, Y.T. and A.S.; methodology, Y.T. and W.H.M.; software, A.S., A.R., and Z.M.; validation, Y.T., A.R., and L.Q.; formal analysis, A.S., Y.T., and A.R.; investigation, Y.T.; resources, Y.T. and W.H.M.; data curation, A.S. and Z.M.; writing—original draft preparation, A.S. and Y.T.; writing—review and editing, Y.T. and Z.M.; visualization, A.S. and W.H.M.; supervision, L.Q.; project administration, L.Q. and W.H.M.; funding acquisition, L.Q. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by The National Natural Science Foundation of China, grant number 7197030867 and the APC was funded by The National Natural Science Foundation Of China (grant number 7197030867).

Institutional Review Board Statement: As the study does not involve any personal data and the respondent was well aware that they can opt-out anytime during the data collection phase, any written institutional review board statement is not required.

Informed Consent Statement: As the study does not involve any personal data and the respondent was well aware that they can opt-out anytime during the data collection phase, any written institutional review board statement is not required.

Data Availability Statement: The associated dataset of the study is available upon request to the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Reliability and Validity Test of Data

The validity and reliability test results of the data used by Cronbach's "α" and factor load are shown in Table A1. The overall Cronbach's "α" coefficient of the scale is significantly higher than 0.8, and the Cronbach's "α" coefficient of each dimension measurement index is significantly higher than 0.7, indicating significant reliability of the data and variables measurement. Besides, the factor load of each measurement index is more than 0.6, which shows that the data of this study are validated, and the selection of indicators is sufficient.

Table A1. Social capital measurement indicators and reliability and validity tests.

Variable	Dimension	Measure Index	Factor Load	Cronbach'α
Social capital	Social network	Number of regular contacts (Unit: person)	0.707	0.784
		Expenses for human relationship gifts (unit: yuan)	0.680	
		Do you often meet with your friends?	0.806	
		Can you get helpful information about marriage, school, and so on from people around you?	0.823	
	Social trust	Do you think people around you keep their promises?	0.798	0.846
		Do you trust strangers?	0.805	
		Would you like to lend something to the people around you?	0.822	
		Do you believe the relevant policies issued by the village committee?	0.839	
	Social prestige	Is your neighbor willing to help when your family is busy?	0.902	0.917
		Do the villagers respect you?	0.913	
		Are there any influential factors in your village that will impact on your opinion?	0.923	
		If there is any problem in your neighbor's house, will you ready to help them?	0.885	
	Social participation	Do you often visit your neighbor's house?	0.896	0.891
		Do you often take part in the village people's weddings, funerals, and other activities?	0.768	
		Do you and the villagers often discuss problems with each other?	0.881	
		Do you often participate in playing cards and communal dances with your neighbor?	0.865	

Note: Factor loading denotes the correlation coefficient for the variable and factor.

Appendix B. Reliability and Validity Test of the Results

The dependent variable of the article is the degree of embracing modern irrigation technology by farmers, and the value range is [0, 1]. If only using OLS to estimate model parameters with censored data, the regression results may not be robust. Therefore, the

Tobit model is adopted to maintain the robustness of OLS estimation. If the core variables in Tobit analysis results are still significant, it has robustness; otherwise, it has no robustness. The estimated results in Tables A2 and A3 of Appendix B are consistent with those in Tables 1 and 2, representing that the above-observed assessment is robust.

Table A2. Robustness test of mediation effects.

Variable	Explained Variable		
	Degree of Technology Adoption (1)	Economic Vulnerability (2)	Degree of Technology Adoption (1)
External shocks	−0.5942 *** (0.1737)	0.0820 ** (0.0360)	−0.5599 *** (0.1723)
Economic vulnerability	-	-	−2.8287 ** (1.3439)
Intercept term	−5.3062 *** (1.5612)	0.4808 *** (0.0384)	−2.2920 ** (1.3288)
Control variable	Yes	Yes	Yes
Wald chi square	47.12 ***	209.45 ***	52.36 ***
R^2	0.2475	0.2804	0.3327

Note: ***, **, * indicate significant differences at 0.01, 0.05, and 0.10 levels, respectively; the figures in brackets are standard errors.

Table A3. Robustness test of the moderator effects.

Variables	Explained Variable		
	Degree of Technology Adoption (4)	Economic Vulnerability (5)	Degree of Technology Adoption (6)
External shocks	−1.0149 *** (0.3302)	0.0076 ** (0.0036)	
Economic vulnerability	-	-	−5.5532 ** (2.4104)
social capital	0.9471 *** (0.3378)	−0.0151 * (0.0079)	3.4129 *** (1.1797)
Formal insurance	0.8039 ** (0.3568)	−0.0196 ** (0.0096)	0.8471 ** (0.3611)
External shock * social capital	0.5843 ** (0.2607)	−0.0125 *** (0.0046)	-
External shock * formal insurance	0.7377 ** (0.3596)	−0.0111 * (0.0066)	-
Economic vulnerability * social capital	-	-	6.2363 *** (2.2249)
Economic vulnerability * formal insurance	-	-	2.1413 *** (0.7565)
Intercept term	−4.5210 *** (1.1820)	0.6048 *** (0.0287)	−6.5661 *** (1.8207)
Control variable	Yes	Yes	Yes
WaldThe square value	64.47 ***	206.83 ***	68.42 ***
R^2	0.2670	0.2769	0.3090

Note: ***, **, * indicate that the assessed results are significant at the level of 0.01, 0.05, and 0.1; the figures in brackets are standard errors.

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