Climate Risk Management 32 (2021) 100283

Contents lists available at ScienceDirect

Climate Risk Management

journal homepage: www.elsevier.com/locate/crm

Climate change risk perceptions, facilitating conditions and health risk management intentions: Evidence from farmers in rural China

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ARTICLE INFO

Keywords:
Climate change
Health risk management
Risk response
Health Belief Theory
China

ABSTRACT

Climate variability exerts severe threats to farmers and agriculture related activities and farmers. A growing number of studies have paid attention to mitigating carbon emission and adapting to climate change. Very few studies, however, have investigated farmers' health risk management associated with climate change. This study, therefore, proposed a hybrid theoretical model to explore the roles of farmers' climate risk perceptions and facilitating conditions in farmers' health risk management, both theoretically and empirically. Using a sample of 1499 rice farmers in China, the partial least squares structural equation modeling (PLS-SEM) was adopted for empirical analysis, and the Multi-group Analysis (MGA) was employed to examine the heterogeneity among farmers' socio-economic status. This study found that farmers' perceived severity of climate change and perceived benefits of addressing climate change have significant impacts on their resources and technical facilitating conditions, in turn, those two types of facilitating conditions significantly impact their health risk management intentions. Subjective norms are also identified as predictors of resources facilitating condition and technical facilitating condition. In addition, farmers with lower income are more likely to suffer from health risks induced by climate change. They have fewer resources for resilience and maintaining health. Based on the findings identified above, strategies for coping with the negative impacts of climate change on farmers' health were proposed for climate adaptation from the perspective of health risk management.

1. Introduction

Climate variability has been continuously posing a threat to agricultural activities and humans' welfare. The scientific community has paid continuous attention to the nexus of agriculture and climate change, and mitigation and adaptation strategies to cope with climatic shocks (Zhang et al., 2020a, 2020b). A large number of studies consider specific adaptation practices in the agricultural sector, such as diversified crop, mixed crop-livestock farming systems, changing farming dates, resistant varieties (Bradshaw et al., 2004;

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https://doi.org/10.1016/j.crm.2021.100283
Received 29 June 2020; Received in revised form 28 January 2021; Accepted 29 January 2021
Available online 9 February 2021
2212-0963/

Abbreviations

CSA	Climate-smart agriculture
GHGs	Greenhouse gases emissions
CSAPs	Climate-smart agricultural practices
TPB	Theory of Planned Behaviour
HBM	Health Belief Model
SPM	Stress Process Model
DTPB	Decomposed Theory of Planned Behaviour
PLS-SEM	Partial least squares structural equation modelling
MGA	Multi-Group Analysis
AVE	Average variance extracted
HTMT	Heterotrait-Monotrait Ratio
VIF	Variance inflation factor
PSCC	Perceived Severity of health problem driven by climate change
PSCC1	Perceived Severity of health problem driven by severe drought
PSCC2	Perceived Severity of health problem driven by irregular rain
PSCC3	Perceived Severity of health problem driven by severe floods
PSCC4	Perceived Severity of health problem driven by severe wind
PSCC5	Perceived Severity of health problem driven by severe high temperatures
PSCC6	Perceived Severity of health problem driven by the increased probability of illness
PBACC	Perceived Benefits to address climate change
SN	Subjective Norms
RFC	Resources facilitating conditions
TFC	Technical facilitating condition
HRMI	Health Risk Management Intentions
HRMI1	Health Risk Management Intentions in an aspect of making more efforts to learn the ways of health protection
HRMI2	Health Risk Management Intentions in an aspect of spending more time on health protection
MICOM	Measurement invariance of composite models
TCM	Traditional Chinese medicine

Tong et al., 2017; Li et al., 2020). Climate-smart agriculture (CSA) has been proposed to achieve agricultural productivity, resilience, and reduce greenhouse gases emissions (GHGs). To achieve these goals, climate-smart agricultural practices (CSAPs) have been explored and implemented world widely (Lipper et al., 2014; Tong et al., 2017), particularly in achieving agricultural productivity and reducing GHGs. On the other hand, efforts have also been made to build resilience to climate change. For example, insurance is gaining importance in providing opportunities to improve climate risk management in developing countries (Surminski et al., 2016), among which crop insurance can help to improve agricultural productivity (Panda et al., 2013). However, one of the limitations of these studies is that they have made efforts into different types of adaptation practices in agriculture but limited research has been done in revealing farmers' health risk management when coping with climate change.

Climate change affects health through a range of pathways, such as resulting in disease occurrence or health risks caused by heat waves, floods, droughts (Haines et al., 2006; Thornton et al., 2014), which exerts negative impacts on humans' health welfare. Floods and droughts can be more frequent in climate variability, which might have negative consequences for human health, particularly when there is inadequate access to basic healthcare (Few, 2007; Agency, 2017). The frequent and severe climate change events pose threats to human's livelihood and well-being (Jose et al., 2018), particularly for the vulnerability groups. Farmers' working environment is exposed to environmental risks caused by climate shocks (Chen and Gong, 2020), thus suffering from vulnerability. Extreme temperature, severe droughts, and irregular raining (Thornton et al., 2014), directly affect the agricultural working environment and finally pose threats to farmers' health. For example, evidence indicates that the rising temperature can cause heat stroke (Nicholas et al., 2021). However, researches from global, regional or sectoral approaches to evaluate the impact of climate change often neglect the effects on individuals' health behaviours (Kovats and Akhtar, 2008), particularly for the farmers whose working conditions are highly exposed to the climatic conditions. Considering that farmers' health lies in the core of their human capital, which is an important capital in achieving farmers' sustainable development and addressing climate change at individual levels, it is imperative to explore farmers' climate risk responses from the perspective of health impacts and health behaviours.

Researchers have paid great attention to improve individuals' adaptation behaviours towards climate change, including agricultural productivity and health protections (Rauf et al., 2017; Andrade et al., 2019; Tong et al., 2019). Determinants of those adaptative behaviours can be grouped into social-psychological determinants including beliefs, perceptions, attitudes and intentions (Mase et al., 2017; Li et al., 2020), and socio-demographical factors, such as economic status, education, age, gender and professionals (Kakota et al., 2011; Van der Linden, 2015; Zhang et al., 2020a, 2020b). Prior studies have used behavioural change theories, such as the theory of planned behaviour (TPB), Health Beliefs Model (HBM) and Risks-Attitudes-Norms-Abilities-Self-regulation (RANAS), to identify the key determinants of individuals' adaptation behaviours, particularly in the agricultural practices (Andrade et al., 2019; Yu et al., 2019;

Zhang et al., 2020a, 2020b). Studies have found that indicators reflecting socio-economic systems such as income are the primary determinants of environmental inequality, with the poor bearing high levels of environmental risks but lower adaptations (Hong et al., 2016; Ali and Erenstein, 2017). Income level, family size, urban/peri-urban background, perceived barriers, perceived benefits and cues to action significantly affect adaptation to heat waves (Rauf et al., 2017). However, there is a paucity of dealing with farmers' adaptative behaviours from a health risk management view, and how farmers' risk perceptions towards the negative health impacts caused by climate change influences their health risk management intentions are still unclear.

To fill the gap identified above, this study will: (1) reveal farmers' climate risk perceptions of health impacts caused by climate change; (2) figure out farmers' response strategies towards health risks associated with climate change; (3) explore the roles of farmers' climate risk perceptions of health and response in health risk management; and (4) illustrate the heterogeneity of socio-demographical factors in farmers' health risk management. Specifically, this study investigates farmers' health risk management response in coping with the pressure caused by climate change on human heath, which is also referred to "health adaptation to climate change". By taking Chinese rice farmers as an example, this study contributes to the existing literature by proposing a theoretical framework to explore farmers' health risk management to cope with climate change at the farm-scale level.

2. Theoretical framework

2.1. Theory of planned behaviour (TPB), health belief model (HBM) and the decomposed theory of planned behaviour (DTPB)

Ajzen (1991) proposed the theory of planned behaviour, which includes four core variables in the TPB: attitude (AT), subjective norm (SN), perceived behaviour control (PBC) and behavioural intention (BI). Following the logical line of "attitude-intention-behaviour", individuals' behavioural intention is the immediate antecedents to behavior (Xu et al., 2020), which has been extensively used as a predictor of final use (Venkatesh et al., 2003). Due to its power in predicting individuals' behaviour, TPB has been widely employed to analyse individuals' risk adaptation behaviours (Wang et al., 2019; Xu et al., 2020). Ajzen (2005) stated that new communication components and structures could be considered to improve this theory. Researchers have extended the TPB by incorporating other variables that can improve the predictive ability of the model (Savari and Gharechaee, 2020; Xu et al., 2020). Evidence has indicated that people's perceptions of climate change risks relate to their actions to mitigate climate change, such as perceived risks both on farmers' activities (Tong et al., 2019), where people who perceived high risk tend to take actions (Haller and Hadler, 2008). In the context of health adaptation to climate change, risk perception of health hazards caused by climate change does have an impact on individuals' response (Ebi and Otmani del Barrio, 2017; Austin et al., 2019).

The health belief model (HBM) was proposed to explore individual health behaviours through model construction and has been employed to estimate individuals' health behaviours (Rosenstock, 1974; Janz and Becker, 1984), which has also been widely used to assess risk perceptions of environmental health (Andrade et al., 2019). Perceived susceptibility and perceived severity in HBM are collectively referred to perceived risks, and perceived benefits are people's belief that taking the proposed actions can effectively reduce the severity of the risk or impacts. Evidence indicates that the HBM can effectively capture motivation and risk perceptions (Andrade et al., 2019). In this study, we adopted the perceived severity and perceived benefits from the HBM to assess farmers' attitudes towards the health problems caused by climate change.

Compared with the theory of planned behaviour (TPB), the Decomposed Theory of Planned Behaviour (DTPB) has subdivided behavioural beliefs, making the influence factors of beliefs more specific, and has a stronger ability to explain and predict behaviours. This decomposed TPB more completely explores the dimensions of perceived behavioural control by decomposing them into specific belief dimensions: self-efficacy, resources facilitating conditions and technology facilitating conditions (Taylor and Todd, 1995; Chawinga and Zinn, 2016). Facilitating conditions refer to individual perceptions of the availability of technological and/or organizational resources including knowledge, resources and opportunities, which can be used to address barriers to a use behavior (Venkatesh et al., 2003). When it comes to individuals' health risk management, the access to resources and technical information and capabilities can have impacts on health coping behaviors (Wang et al., 2019). According to the definition used by Venkatesh et al. (2003), this paper introduced the farmers' health risk coping ability from the perspectives of resources facilitating condition and technology facilitating condition. We defined the resources facilitating condition of active response to climate change on human health with the item "resources facilitating condition". This included the resources that a farmer can obtain when dealing with health hazards caused by climate change. Similarly, the "technical facilitating condition" was identified as farmers' access to technical facilitating condition to address the negative impact of climate change on human health, such as basic medical skills and preventive skills of mitigating the negative impacts caused by climate change on their health. In addition, there might exist systematic differences in coping resources and methods (Ali and Erenstein, 2017; Rauf et al., 2017), and how farmers' perceptions towards the negative impacts caused by climate change their health behaviours is still unclear. Therefore, the socio-economic impacts on farmers' health risk management intentions need be taken into consideration to explore the intergroup differences regards to health risk management intentions.

2.2. The application of a hybrid conceptual model: farmers' health risk management model

While prior researches have deployed the extended TPB and HBM to investigate the process of individuals' health behaviours, limited studies reveal the process of farmers' health risk management intentions to address the negative impacts caused by climate change. Although previous studies have focused on revealing farmers' adaptation behaviours of climate change associated with agricultural activities, it is imperative to further investigate the behavioural factors that affect farmers' decision-making process of health behaviours to cope with climate change. To our knowledge, no prior study has investigated farmers' health risk management in addressing climate change in the rice sector. To fill this gap, this study built a hybrid model to explore farmers' climate risk responses from the perspectives of health impacts and health risk management intentions. As limited evidence has been found in revealing farmers' health adaptation behaviour, this study focused on the decision process of farmers' risk management intentions to reveal to what degree a farmer has formulated conscious plans to perform or not perform specified future behaviour in health adaptation to climate change (Warshaw and Davis, 1985). This study assumed that farmers' health risk management intentions can be affected by their accessible conditions in both resources and technical. We also assumed that the farmers' climate risk perceptions and facilitating conditions towards health risk management intentions in addressing climate change vary across different socio-economic status groups. Based on those assumptions, we built the conceptual model of farmers' health risk management intentions (HRMI), which is presented in Fig. 1, and the definition of each construct was shown in the Appendix Table A1.

3. Methods

3.1. Data collection

Like other countries, China faces challenges caused by climate change, and therefore a more resilient agricultural system is required to achieve national food security. Due to its suitable growing conditions for rice cultivation, such as good soil conditions and adequate precipitation, Hubei province represents as one of the main rice production areas in China (Zhang et al., 2020a, 2020b). According to the National Bureau of Statistics of China, the rice yield of Hubei province accounted for 10% of the rice yields in China in 2018. Despite the high-quality rice production environment including good soil conditions and adequate precipitation, climate shocks and weather variability negatively affect the agriculture in this area (Tong et al., 2019). Although farmers in this region have adopted climate smart agricultural practices and crop insurance to cope with the shocks of climate changes on agricultural production, less attention has been paid to the risk management to protect farmers' health welfare. In this study, we took Hubei province as a case study to explore farmers' climate risk perceptions and health coping strategies towards climate change.

A questionnaire was firstly designed according to the conceptual model built in the former part. Farmers' socio-demographical factors were also designed by proxies, such as economic status measured by per capita income, education level measured by educated years and farming experience measured by farmers' engaging in farming works. Besides, farmers' age, gender and reliability on farming activities were also recorded. Data were collected via surveys conducted face-to-face in 2018 in Hubei province by trained postgraduates from the lead author' university. The multi-stage sampling (i.e. stratified sampling and random sampling), were combined for the sample selection. Firstly, nine counties were randomly selected in Hubei province: Jianglin, Shayang, Jianli, Xiaogan, Honghu, Xianning, Wuxue, Qichun and Xiantao. These nine counties are all located in the middle reach of the Yangtze River and have similar climate conditions and farming activities. In each selected county, two to three towns were selected in each county, and then two administrative villages were randomly selected from each sample town. Finally, around 45 farmers were randomly selected from each sample village. A total of 1,752 valid questionnaires were completed through surveys, among which 253 respondents were excluded due to the missing values and inconsistencies. Therefore, the final sample was 1,499 for testing the conceptual model explored in this study.

The demographic information of the sample is given in Table 1. Each category has been divided into two groups: high group and low group according to the thresholds of 4000RMB for annual per capita income, 7 years for educational experience, 30 years for farming experience, 60 years for age and 50% for the farming reliability as an income source. The demographical information indicates that around 64% of the farmers reported that they had farming experience for more than 30 years. Around 17% of the farmers had an insufficient economic status. In addition, about 40% of the farmers relied on agricultural activities as their main income source.

3.2. Model estimation procedure

The partial least squares structural equation modeling (PLS-SEM) was adopted to test the conceptual model and measure the complex causality correlations (Afthanorhan, 2013; Hair et al., 2016). The exploratory factor analysis was firstly conducted to explore the structure of factors. The KMO was 0.862 and significant at 0.01 level, indicating that the data were suitable to do factor analysis. Factors with a loading lower than 0.6 were dropped (i.e. PSCC3, PSCC4, SN4 and HRMI3). The PLS-SEM procedure proposed by Hair

Table 1
Demographical information of the sample.

Variable	Number	Proportion	Variable	Number	Proportion
Farming experience			***Farmers' Education***		
<=30 years	541	36.09%	<=7 years	1047	69.85%
>30 years	958	63.91%	>7 years	452	30.15%
Farmers' Age			***Gender***		
<=60 years	849	56.64%	Male	1126	75.12%
>60 years	650	43.36%	Female	373	24.88%
Economic status			***Agricultural reliability***		
<= 0.4 k RMB	264	17.61%	<= 50%	878	58.57%
>0.4 k RMB	1235	82.39%	> 50%	621	41.43%

et al. (2016) was applied for model estimation. The heterogeneity of socio-economic factors was estimated by using the independent *t* test and multi-group analysis (MGA) procedure (Henseler, 2012). Firstly, the independent *t* test was conducted based on the latent variable calculated by the Algorithm of PLS-SEM estimation, to figure out the difference among different groups. Then, the MGA was employed to explore the difference of paths in the HRMI model in terms of farmers' age, education level, economic status, farming experience, gender and farming reliability.

4. Results

4.1. Model test and explanation for farmers' climate change health response model

The test of measurement models indicated that the measurement models built in this study had reached a suitable level both for reliability and validity. The composite reliabilities were higher than 0.8 for each construct (Hair et al., 2011, 2012). The loadings in the models were shown in Table 2, each of them was close to or above 0.7. Although there were two indicators for PSCC were lower than the threshold, we kept these two indicators in the measurement models to get a full understanding of farmers' perceptions towards the negative impacts caused by climate change. The validity of each measurement model was evaluated in terms of convergent validity and discriminant validity. The average variance extracted (AVE) was higher than 0.5 for each construct, indicating a good quality for the convergent validity. The Fornell-Larcker Criterion and Heterotrait-Monotrait Ratio (HTMT) for the measurement models were all lower than the threshold value (Henseler et al., 2015), indicating high validity for the measurement models, and the results were shown in Table 3. The variance inflation factor (VIF) of each observed indicator was less than 3.5, which means that the model passed the test for multicollinearity.

The structural model was estimated via coefficients of determination, cross-validated redundancy, the effect size, and the results indicated a good fit for the HRMI model. The path coefficients and significance were generated from a bootstrapping process with a set of 5000 subsamples and the results were shown in Table 4. Results illustrated that both farmers' perceived severity of health problems driven by climate change and perceived benefits to address climate change significantly affected farmers' resources facilitating condition, with the former factor had a larger impact compared with the latter one. Similarly, farmers' technical facilitating condition was affected by farmers' perceived severity of health problems driven by climate change and perceived benefits to address it. Contrary to the power found in resources facilitating condition, farmers' technical facilitating condition was more likely to be driven by their perceived benefits from active response to climate change. Subjective norms were found have significant impacts both on farmers' resources facilitating condition and technical facilitating condition, with a higher power from the latter one. Compared with technical facilitating condition, resources facilitating condition was more powerful in predicting farmers' health risk management intentions.

4.2. Differences for demographical factors

Results from the independent test for each latent variable for each group were shown in Table A2 in Appendix, and the differences across the groups were explored in each group category. The economic factor and education factor were found out with a greater significant difference in the divided groups. Specifically, the reported health risk management intentions of the higher economic group were significantly greater than that of the lower economic group ($t = -1.956$, $p = 0.051$). A significant positive difference was also found in PBACC, PSCC, SN and RFC. However, compared with the significant difference found in RFC, there was no difference found for the TFC in the two groups divided by economic status. The results indicated that, compared with the lower economic group, farmers for the higher economic group had stronger awareness of the negative impact caused by climate change on human health, and stronger perceptions of benefits for actively responding to the climate change. The higher economic group was reported to have more resources

Table 2
Reliability of measurement model.

	Loading	VIF	Cronbach's alpha	CR	AVE
PSCC			0.7112	0.8143	0.5263
PSCC1	0.6098	1.4523			
PSCC2	0.8027	1.5891			
PSCC5	0.7997	1.7151			
PSCC6	0.6704	1.6277			
PBACC			0.8358	0.8127	0.6875
PBACC 1	0.8032	1.6587			
PBACC 2	0.7740	1.1122			
PBACC 3	0.8661	2.1713			
PBACC4	0.8276	2.0068			
SN			0.8505	0.9099	0.7718
SN1	0.9201	3.1098			
SN2	0.7861	1.5777			
SN3	0.9224	3.3845			
HRMI			0.5729	0.8127	0.6875
HRMI1	0.9224	1.1921			
HRMI2	0.7241	1.1921			

Table 3
Fornell-Larcker Criterion and Heterotrait-Monotrait Ratio (HTMT) of measurement models.

	HRMI	PBACC	PSCC	RFC	SN	TFC
HRMI	0.8292					
PBACC	0.4382 (0.5969)	0.8184				
PSCC	0.1563 (0.2524)	0.4428 (0.5167)	0.7255			
RFC	0.6037 (0.7521)	0.3843 (0.4167)	0.3127 (0.3359)	1.0000		
SN	0.4204 (0.5701)	0.6044 (0.7207)	0.4953 (0.5816)	0.4181 (0.4494)	0.8785	
TFC	0.4534 (0.5594)	0.3504 (0.3793)	0.3375 (0.3698)	0.6720 (0.6720)	0.4336 (0.4644)	1.0000

Table 4
Bootstrapping results of structural model estimation.

Path	Coefficient	T value	S.D.	CI Lower	CI Upper
PBACC → RFC	0.1846***	5.9414	0.0309	0.1239	0.2453
PBACC → TFC	0.1072***	3.6491	0.0293	0.0513	0.1635
PSCC → RFC	0.1066***	3.4906	0.0301	0.0464	0.1637
PSCC → TFC	0.1433***	4.8803	0.0291	0.0862	0.2001
RFC → HRMI	0.5463***	18.1637	0.03	0.4869	0.6046
SN → RFC	0.2538***	8.1409	0.0313	0.1905	0.3151
SN → TFC	0.2974***	10.0871	0.0296	0.2386	0.3539
TFC → HRMI	0.0863***	2.9571	0.0294	0.0289	0.1427

to respond to climate change compared with the lower economic group.

Farmers with higher education level were more likely to give efforts to health response, as they had higher perceived benefits and perceived severity when facing climate change. The subjective norms for the higher education level were observed higher compared with farmers in the lower group. Again, no significant difference was found between the two groups divided by education level. It is worth noting that for the majority discussed in this study, farmers were found more accessible to resources facilitating condition than technical facilitating condition, which indicated that farmers have difficult access to technical facilitating condition to climate change in this region. Fig. 2 indicated that 85.26% of farmers felt the influence of climate change (PSCC 6) on increasing the probability of illness, meaning that most farmers had realized the negative effects of climate change on their health, especially severe drought.

For the group difference found in agricultural reliability, a significant difference was observed for health risk management intentions, while no other difference was found for the reminding latent factors. The results indicated that compared with the lower agricultural reliability group, farmers with higher agricultural reliability were more likely to invest in health to address the negative effects caused by climate change. Similarly, compared with the elder, the younger group had significant great passion to invest in health. Farmers with longer farming experience perceived greater benefits for coping with climate change compared with farmers with shorter farming experience. Results for gender showed that men were more likely to give investment to health care compared with women, indicating that women were less involved in the health risk management intentions to cope with negative impacts caused by climate change.

Fig. 3 and Fig. 4 indicated the distributions of farmers' climate risk perceptions, their available facilitating conditions and health risk management intentions to climate change. There was a significant difference in the divided groups for the different aspects of farmers' facilitating conditions and health risk management intentions. For the group divided by farmers' education, gender and age, higher education, male and younger groups felt more intensely about the negative effects of climate change on health. As for

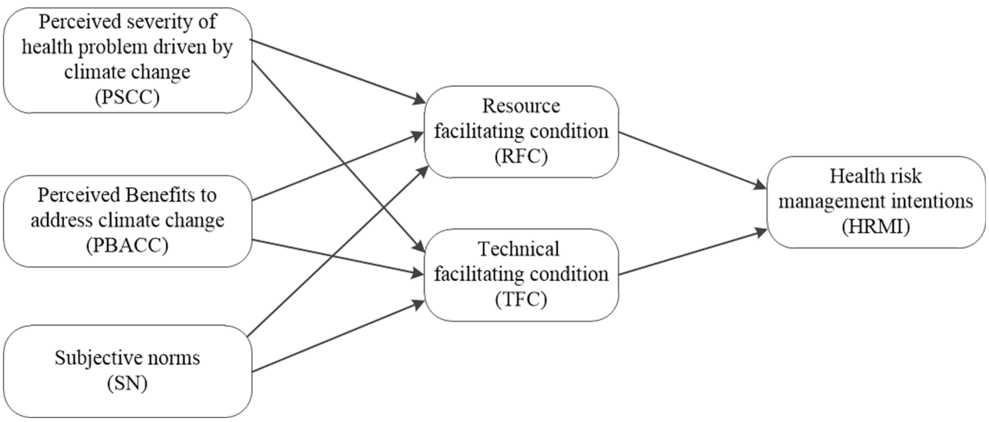

Fig. 1. The conceptual model of farmers' health risk management intentions (HRMI).

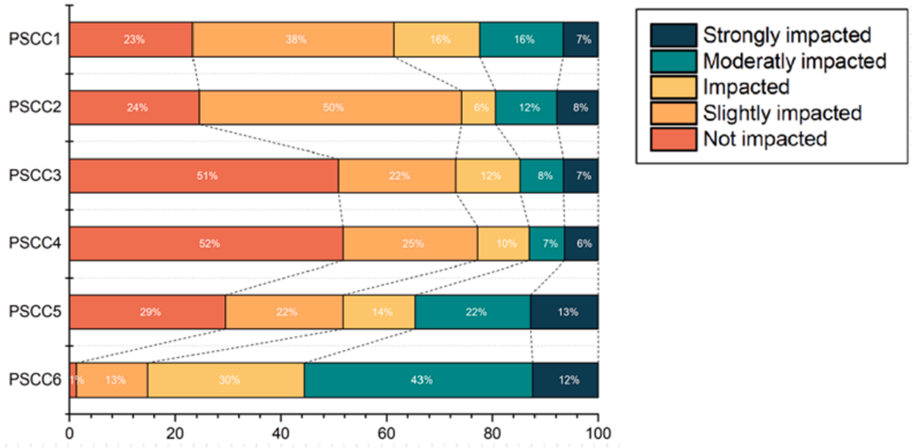

Fig. 2. Proportion of farmers who held different views about the effect of climate change on health. % indicates the percentage of farmers who thought climate change could impact, or moderately impact, or strongly impact their health. PSCC1- health impact of severe drought, PSCC2-health impact of irregular rain, PSCC3-health impact of severe floods, PSCC4-health impact of severe wind, PSCC5-health impact of severe high temperatures, PSCC6-the negative effect of climate change will increase the probability of illness.

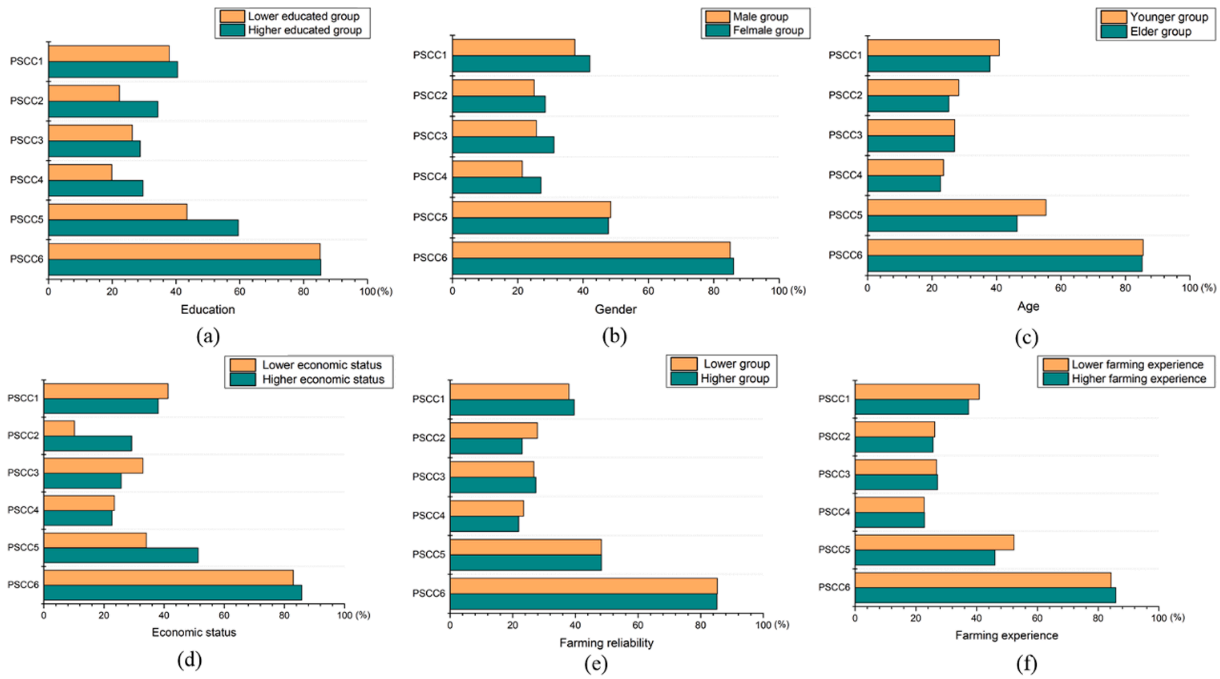

Fig. 3. Proportion of farmers who felt the influence of climate change on health in different groups. Y-axis variable indicates the percentage of farmers who thought climate change could impact, moderately impact, or strongly impact their health in different groups. PSCC1- health impact of severe drought, PSCC2-health impact of irregular rain, PSCC3-health impact of severe floods, PSCC4-health impact of severe wind, PSCC5-health impact of severe high temperatures, PSCC6-the negative effect of climate change will increase the probability of illness.

facilitating conditions to climate change, younger farmers were more accessible to resources and technical conditions. In the terms of health risk management intentions, farmers with lower farming experience had more passion to invest efforts and money in health protection for coping with the negative effects of climate change.

4.3. Heterogeneity of demographical factors on HRMI model

The measurement invariance is viewed as a precondition for multigroup analysis among composites. Following the three-step procedure proposed by Sinkovics et al. (2016), we conducted the measurement invariance of composite models (MICOM)

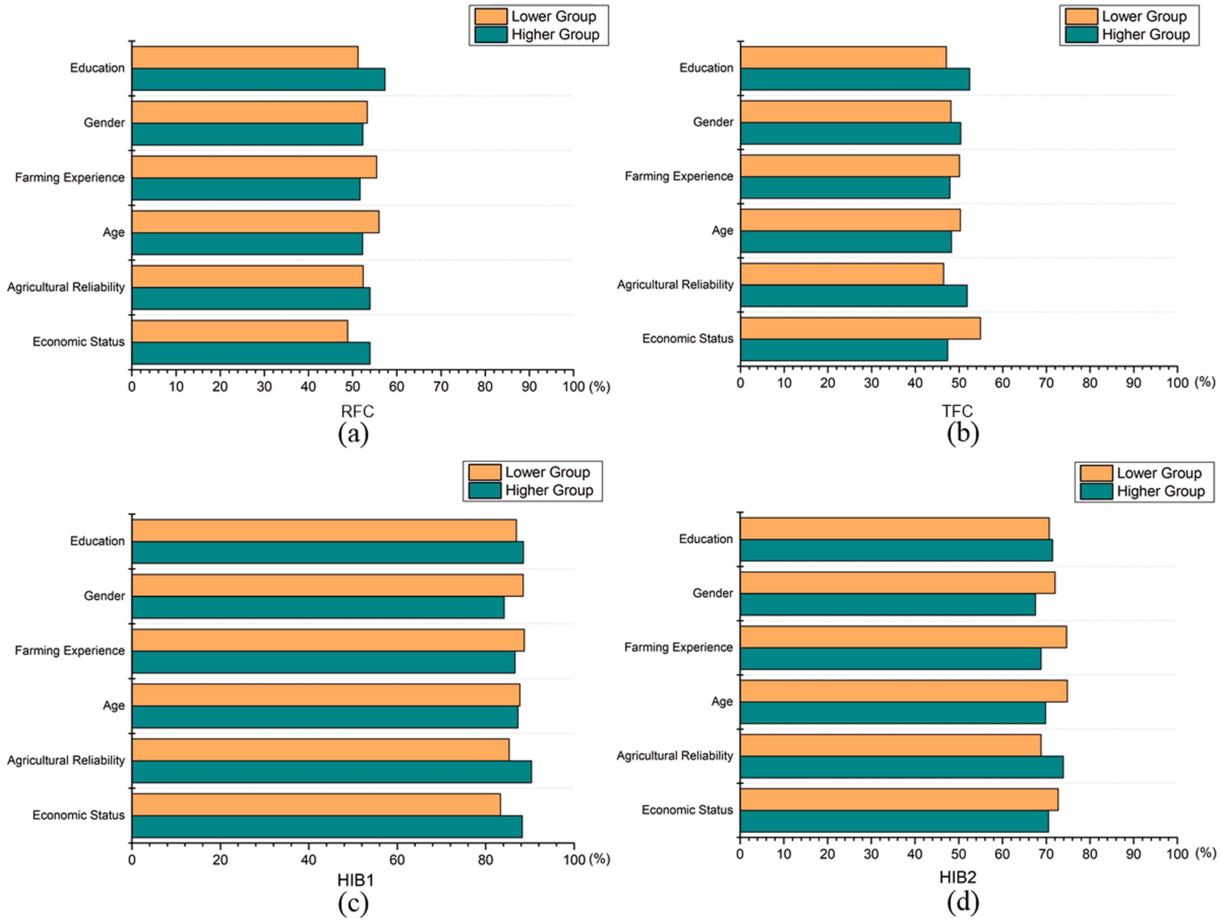

Fig. 4. Proportion of farmers who were willing to have resources facilitating condition (RFC), technical facilitating conditon (TFC), and health risk management intentions (HRMI) to climate change in different groups. Y-axis variable indicates the percentage of farmers who agreed, comparatively agreed or fully agreed to have RFC, TFC and HRMI to climate change. PSCC1- health impact of severe drought, PSCC2-health impact of irregular rain, PSCC3-health impact of severe floods, PSCC4-health impact of severe wind, PSCC5-health impact of severe high temperatures, PSCC6-the negative effect of climate change will increase the probability of illness. RFC-Resources Facilitating condition, TFC-Technical Facilitating Condition. HRMI1- more efforts on learning the ways of health protection, HRMI2- more time on health protection.

procedure to assess the measurement invariance. Results of MICOM indicated that the subgroups divided by economic status and education level failed to meet the criteria, therefore it was inappropriate for the multigroup analysis, where the test results indicated that full measurement invariances had been established for the subgroups divided by age, gender, farming year and farming reliability. The MGA was conducted and results were shown in Table 5. The heterogeneity of age was explored into dichotomous groups by taking 60 years as the thresholds. The relationships for the built health investment intentions model were robust for many of the paths except for the path “PSCC → TFC”. Compared with the significant impacts found in elder group from perceived severity of health problems driven by climate change to technical facilitating condition, this impact was not significant for the younger group. Farmers who were more than 60 years old were predicted greater explanatory power compared with farmers who were 60 years old or less, although the difference among these two groups was not significant through the difference test of coefficients difference test. The difference for gender test indicated that the eight proposed hypotheses were supported for male group and seven for female group. The perceived severity of health problem driven by climate change (PBACC) was not found to show a significant impact on technical facilitating condition for the female group, compared with that a positive significant effect was identified for the male group. There was a significant difference in the paths of “PSCC → RFC” and “PSCC → TFC” for these two groups, with the female group have larger impacts on both resources facilitating condition and technical facilitating condition to climate change.

Farmers were divided into two groups by taking 30 years as the threshold of farming experience. The heterogeneity for farming experience indicated that the relationships were robust for both farmers with higher farming experience and with lower farming experience, and no significant difference was found for these two groups. Farmers’ resources facilitating condition was proved to have greater power in farmers’ investment intentions in both groups, while the effects for technical facilitating condition were less. As for the heterogeneity for farming reliability, the hypotheses were all supported for the higher farming reliability group, compared with 6 hypotheses were supported for the lower group, where no significant effects were found in the paths of PBACC to RFC and TFC to

Table 5
Heterogeneity estimation results of demographical factors on HRMI model using MGA.

	Age			Gender			Farming year			Farming reliability		
	lower	upper	Diff	Male	Female	Diff	lower	upper	Diff	lower	upper	Diff
PBACC → RFC	0.1684***	0.0931***	0.0734	0.1048***	0.1289**	0.0175	0.1239**	0.1014**	0.0253	0.0505	0.1911***	0.1387**
	(0.0594)	(0.0337)		(0.0367)	(0.0558)		(0.0513)	(0.0374)		(0.0411)	(0.0435)	
PBACC → TFC	0.1573**	0.1463***	0.0082	0.1711***	0.0677	0.1078	0.1709***	0.1323***	0.0394	0.1249***	0.1755***	0.051
	(0.0665)	(0.0310)		(0.0342)	(0.0573)		(0.0479)	(0.0350)		(0.0358)	(0.0436)	
PSCC → RFC	0.1203*	0.2014***	0.0856	0.1536***	0.2682***	0.1165*	0.1388**	0.2145***	0.0774	0.2277***	0.1149**	0.1146*
	(0.0691)	(0.0334)		(0.0351)	(0.0565)		(0.0543)	(0.0361)		(0.0418)	(0.0472)	
PSCC → TFC	0.0769	0.1135***	0.041	0.0761**	0.1892***	0.1169*	0.1049*	0.1106***	0.0062	0.1212***	0.0886**	0.0345
	(0.0607)	(0.0322)		(0.0315)	(0.0560)		(0.0538)	(0.0346)		(0.0374)	(0.0425)	
RFC → HRMI	0.5588***	0.5430***	0.0119	0.5549***	0.5134***	0.0393	0.5552***	0.5428***	0.0087	0.6284***	0.4525***	0.1845***
	(0.0594)	(0.0347)		(0.0340)	(0.0693)		(0.0493)	(0.041)		(0.0362)	(0.0479)	
SN → RFC	0.3038***	0.2432***	0.0636	0.2767***	0.1922***	0.0845	0.3136***	0.2206***	0.095	0.2354***	0.2844***	0.0464
	(0.0704)	(0.0361)		(0.0366)	(0.0618)		(0.0553)	(0.0414)		(0.0428)	(0.0451)	
SN → TFC	0.3694***	0.2788***	0.0951	0.3069***	0.2964***	0.0125	0.3041***	0.2943***	0.0107	0.2499***	0.3704***	0.1210**
	(0.0603)	(0.0343)		(0.0315)	(0.0601)		(0.0498)	(0.0369)		(0.0371)	(0.0453)	
TFC → HRMI	0.1025*	0.0812**	0.0239	0.0753**	0.1348**	0.0582	0.0777*	0.0891**	0.0089	0.0482	0.1143**	0.0733
	(0.0562)	(0.0337)		(0.0328)	(0.0650)		(0.0466)	(0.0393)		(0.0352)	(0.0466)	

HRMI. For farmers with lower reliability for farming, no significant influence was found in the path of technical facilitating condition to health risk management intentions. Significant differences were found in these two groups in the paths of "PBACC → RFC", "PSCC → RFC", "RFC → HRMI" and "SN → TFC". Results indicated that subjective norms (SN) had been proved to be significant for both groups, with the higher farming reliability has a higher effect. On the contrary, the effects of RFC to HRMI of the lower farming reliability group were significantly higher than that of the farmers with higher farming reliability.

5. Discussion

Understanding farmers' attitudes and response to climate change is an essential task for achieving farmers' health welfare. This study, therefore, proposed a conceptual model of farmers' health risk management intentions in coping with the pressure caused by climate change on human health. Results showed that a moderate amount of variance in farmers' health investment intentions can be explained by factors identified in this study: perceived severity of health problems driven by climate change, perceived benefits to address climate change, subjective norms, resources facilitating condition and technical facilitating condition. Based on these findings, this study discussed the potential strategies to improve farmers' health risk management to address the negative health impacts caused by climate change.

5.1. Psychological determinants of farmers' health adaptation to climate change

With an increasing frequency of extreme weather events caused by climate change, there is a greater risk of adverse human health effects. It is necessary for individuals and communities to develop interventions based on sociological and psychological elements to protect health (Andrade et al., 2019). The subjective norms in this study were found have a positive effect on farmers' resources facilitating condition and technical facilitating condition for health risk management. Among the indicators that construct the measurement model of subjective norms, the community played a significant role in forming farmers' subjective norms. This can be further divided into social network around farmers, as well as the motivation and leading impact from the village leader. This was similar to the finding of Ebi and Semenza (2008), which indicated that the community-based adaptation to increase local adaptive and social capacity can help the communities better prepare for and respond to the health risks of climate change. Therefore, the village level can be a suitable target to put forward strategies for addressing health problems caused by climate change.

Farmers' facilitating conditions to address climate change were explored from both resources condition and technical condition. Farmers show a higher adaption intention when they perceive higher climate risks (Luu et al., 2019), and their adaptations to climate change and disaster preparedness are inherently associated and potentially mutually reinforcing (Bollettino et al., 2020). Zhang et al. (2020a), Zhang et al. (2020b) find that farmers who believed that climate change would affect their health are more willing to implement adaptation measures. However, a gap between perception/knowledge and behaviour still exists in rural areas (Zhang et al., 2017). Our findings indicated that the resources played a significant impact on farmers' health management intentions under climate change. By contrast, the technical facilitating condition played a rather moderate effect on coping with climate change. The comparison also indicated that the technical facilitating condition level was lower than that of resources facilitating condition. Different from the technical skills accessible for coping farming practices to mitigate and adapt to climate change (Watanabe and Kume, 2009; Tong et al., 2017), farmers were found to have less access to the technical strategies for health protection to cope with climate change. Some researches indicated that although people can perceive the high risks, they have limited willingness and strategies to deal with them (Li et al., 2019a, 2019b). Valois et al. (2020) verified that people who have experienced floods are more likely to take preventive actions than people who have never experienced such events. Thus, more attention should be given to help farmers to gain more technical ability to cope with climate change. Originated from the folk, traditional Chinese medicine (TCM) experience is farmers' accumulation in fighting with diseases. TCM has been proved to be a simple, convenient, cheap and effective way for farmers to deal with health problems. The main reason for this was that it can mitigate the difficulty and high costs of getting medical services for farmers. Evidence also showed that the Chinese medicine fits well with the current policy guideline in hierarchical medical system (Zhang, 2017), which makes medical resources accessible across public in different regions. Therefore, education held for training among farmers with TCM could be developed to improve farmers' technical conditions for health risk management.

5.2. Social determinants to farmers' health adaptation to climate change

Respondents had high perceptions of perceived benefits to address climate change, and moderate perceptions of the severity of health problems driven by climate change. This also varied across farmers with different socio-economic status. Findings of this study indicated that the perceived severity of health problems driven by climate change and the perceived benefits to address climate change were higher in higher educated and higher economic status communities. Compared with Zahran et al. (2008) and Yeo and Blong (2010), who found that the elderly, males and poor communities experience more flood-related risk, this study illustrated that the poor community did not sensitively have a larger exposure to climate change compared with the higher economic community, and no significant differences were found for the elder and males. This is different from Williams et al. (2019)'s findings where men and the elderly have the lower heat risk perception. Researches also reveal that ethnic group, health status, marital status, gender, and employment will affect risk perceptions of hot weather, which could significantly affect the coping response (Ye et al., 2018; Li et al., 2019a, 2019b). In general, our findings indicated that the higher education and higher economic communities were more likely to have a larger perception of severity and benefit of coping with climate variability, and therefore, more likely to invest more in health risk management. Thus, the less educated and the poor groups should be given more attention by organizing training purposes to address the negative health impacts caused by climate change.

6. Conclusions, limitations and future research implications

This study explored farmers' health risk management intentions under the driven force of health problems caused by climate change. A hybrid theoretical model – "health risk management intentions (HRMI)" was firstly proposed and then tested by using PLS-SEM with survey data collected with Chinese farmers. By doing so, this study provided a novel empirical contribution to the scientific community by focusing on the farm-scale health risk management, which can also be employed in similar regions or countries. Results indicated that farmers' perceived severity of climate change and perceived benefits for addressing climate change had significant impacts on their resources and technical facilitating conditions, with the resources facilitating condition playing a vital role in improving health risk management intentions, and eventually in health risk management behaviours. Findings also revealed that the HRMI model built in this study can be used to predict farmers' health risk management intentions, as well as identify the vulnerable key points for climate adaptation from the health risk management perspective. Heterogeneity results of farmers' socio-demographics suggested that farmers with higher education level and economic ability have high response level to cope with the health risks caused by climate change, measured by technical and resources facilitating conditions. Therefore, more attention should be put on the less developed groups for helping them to gain more access to resources and technical facilitating conditions to manage health risk associated with climate change. Besides, subjective norms can also be further explored to disseminate the resources and technical facilitating conditions among different farmer groups.

Although the findings of this study provide insights into improving farmers' health adaptation to climate change, it is worth pointing out that the data analysis in this study was conducted with cross-sectional data, thus, we are cautious in claiming the results where we assessed farmers' health risk perceptions and facilitating conditions from a statis perspective. Future studies can be explored from a quasi-experimental angle, with time-series data, to deliver more robust intervention strategies to improve farmers' health risk management intentions towards climate change. Besides, notwithstanding that we captured farmers' health response by using Likert scale questions, we still need to be cautious to reveal the effective measures that can be implemented to improve farmers' health risk management due to data availability. In addition, our findings revealed that farmers living in the insufficient economic group were suffering from the shortages of both resources and technical facilitating conditions. Therefore, future studies should be explored within this vulnerability group for designing effective interventions, particularly with the achievement of health equity. Future studies that take a wholistic scale which include both the vulnerability and the equity to achieve basic health risk management practices can help to give insights to farmers' health adaptations to climate change.

Declarations

Ethical approval and consent to participate: This research received ethical approval (completed by corresponding author) from the ethics committee of Huazhong Agricultural University before commencing data collection. All procedures performed in the studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. And informed consent was obtained from all individual participants included in this study.

Consent for publication: Not applicable.

Availability of data and materials: Not applicable.

Funding: This work was supported by the National Natural Science Foundation of China (72003075; 42071157); the China Post-doctoral Science Foundation (2019T120736; 2020T130231; 2018M640790; 2019M652672); the Philosophy and Social Sciences by Ministry of Education (20YJC630065), and the Fundamental Research Funds for the Central Universities (2662017PY045; 2662020JGPYG11).

CRediT authorship contribution statement

Wenjing Li: Conceptualization, Methodology, Software, Formal analysis, Writing - original draft, Writing - review & editing, Funding acquisition, Project administration. **Kai Yuan:** Methodology, Software, Formal analysis, Writing - original draft, Writing - review & editing. **Meng Yue:** Writing - review & editing. **Lu Zhang:** Conceptualization, Writing - review & editing, Funding acquisition, Project administration. **Fubin Huang:** Software, Formal analysis, Writing - original draft, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We thank all the contributions from the students, farmers and local leaders who participated in data collections.

Appendix

Table A1. Measurements of constructs

Indicators	Description
Perceived Severity of health problem driven by climate change (PSCC)	
PSCC1	The negative impact of severe drought on my health.
PSCC2	The negative impact of irregular rain on my health.
PSCC3	The negative impact of severe floods on my health.
PSCC4	The negative impact of severe wind on my health.
PSCC5	The negative impact of severe high temperatures on my health.
PSCC6	The negative effect of climate change will increase the probability of illness.
Perceived Benefits to address climate change (PBACC)	
PBACC1	Active response to climate change is good for everyone.
PBACC2	Active response to climate change allows me to live a higher quality of life.
PBACC3	Reducing greenhouse gas emissions could help delay climate change.
PBACC4	Climate change adaptation can help eliminate negative effects.
Subjective Norms (SN)	
SN1	My neighbors think I should take climate change action.
SN2	I have a responsibility to respond to climate change.
SN3	Village cadres think I should take climate change action.
SN4	My families think I should take climate change action.
Resources Facilitating Conditions (RFC)	
RFC1	I have the resources needed to respond to the negative impact caused by climate change on health.
Technical Facilitating Conditions (TFC)	
TR1	I have the technical skills to respond to the negative impact caused by climate change on health.
Health Risk Management Intentions (HRMI)	
HRMI1	I will give more efforts to learn the ways of health protection.
HRMI2	I am likely to spend more money on health protection.
HRMI3	I will give more time to health protection.

Table A2 Independent sample test for group variables

Group variable	Indicator	Category	N	Mean	S.D.	S.E.	Test for equality of variances	*t*-test for Equality of Means	Sig. of *t*-test for Equality of Means
Economic	NHRMI	Lower	264	0.5692	0.1898	0.0117	Equal	−1.956	0.051
		Higher	1235	0.5957	0.2019	0.0057	0.865		
	NPBACC	Lower	264	0.6005	0.1638	0.0101	Unequal	−5.007	0.000
		Higher	1235	0.6570	0.1772	0.0050	0.071		
	NPSCC	Lower	264	0.3717	0.1666	0.0103	Unequal	−8.483	0.000
		Higher	1235	0.4738	0.2212	0.0063	0.000		
	NSN	Lower	264	0.5639	0.2117	0.0130	Unequal	−3.840	0.000
		Higher	1235	0.6214	0.2581	0.0073	0.000		
	NRFC	Lower	264	0.4148	0.2395	0.0147	Unequal	−2.964	0.003
		Higher	1235	0.4640	0.2680	0.0076	0.014		
	NTFC	Lower	264	0.4337	0.3019	0.0186	Unequal	0.044	0.965
		Higher	1235	0.4328	0.3319	0.0094	0.000		
Agricultural reliability	NHRMI	Lower	878	0.5794	0.2031	0.0069	Equal	−2.686	0.007
		Higher	621	0.6075	0.1945	0.0078	0.763		
	NPBACC	Lower	878	0.6494	0.1798	0.0061	Unequal	0.614	0.539
		Higher	621	0.6437	0.1710	0.0069	0.054		
	NPSCC	Lower	878	0.4635	0.2195	0.0074	Equal	1.631	0.103
		Higher	621	0.4450	0.2109	0.0085	0.435		
	NSN	Lower	878	0.6129	0.2570	0.0087	Unequal	0.314	0.753
		Higher	621	0.6088	0.2436	0.0098	0.015		
	NRFC	Lower	878	0.4539	0.2648	0.0089	Equal	−0.250	0.803
		Higher	621	0.4573	0.2626	0.0105	0.684		
	NTFC	Lower	878	0.4245	0.3314	0.0112	Unequal	−1.193	0.233
		Higher	621	0.4448	0.3198	0.0128	0.084		
Age	NHRMI	Lower	849	0.6107	0.2039	0.0114	Equal	1.979	0.048
		Higher	650	0.5858	0.1987	0.0058	0.738		
	NPBACC	Lower	849	0.6486	0.1701	0.0095	Equal	0.182	0.856
		Higher	650	0.6466	0.1778	0.0052	0.164		
	NPSCC	Lower	849	0.4712	0.2111	0.0118	Equal	1.432	0.152
		Higher	650	0.4517	0.2173	0.0063	0.612		
	NSN	Lower	849	0.6156	0.2501	0.0140	Equal	0.352	0.725
		Higher	650	0.6101	0.2519	0.0073	0.738		
	NRFC	Lower	849	0.4756	0.2642	0.0148	Equal	1.549	0.122
		Higher	650	0.4498	0.2636	0.0077	1.000		
	NTFC	Lower	849	0.4450	0.3330	0.0187	Equal	0.739	0.460
		Higher	650	0.4297	0.3250	0.0095	0.373		
Farming year	NHRMI	Lower	541	0.5990	0.1959	0.0084	Equal	1.163	0.245
		Higher	958	0.5865	0.2022	0.0065	0.119		
	NPBACC	Lower	541	0.6367	0.1735	0.0075	Equal	−1.707	0.088

(continued on next page)

Table A2 Independent sample test for group variables (*continued*)

Group variable	Indicator	Category	N	Mean	S.D.	S.E.	Test for equality of variances	*t*-test for Equality of Means	Sig. of *t*-test for Equality of Means
		Higher	958	0.6529	0.1775	0.0057	0.572		
	NPSCC	Lower	541	0.4580	0.2058	0.0088	Unequal	0.298	0.766
		Higher	958	0.4546	0.2218	0.0072	0.033		
	NSN	Lower	541	0.6075	0.2444	0.0105	Unequal	−0.439	0.660
		Higher	958	0.6134	0.2554	0.0083	0.067		
	NRFC	Lower	541	0.4649	0.2567	0.0110	Unequal	1.069	0.285
		Higher	958	0.4499	0.2677	0.0086	0.093		
	NTFC	Lower	541	0.4367	0.3239	0.0139	Equal	0.333	0.739
		Higher	958	0.4308	0.3284	0.0106	0.411		
Gender	NHRMI	Male	1126	0.5975	0.1976	0.0059	Unequal	2.132	0.033
		Female	373	0.5715	0.2061	0.0107	0.221		
	NPBACC	Male	1126	0.6441	0.1732	0.0052	Unequal	−1.081	0.280
		Female	373	0.6559	0.1847	0.0096	0.046		
	NPSCC	Male	1126	0.4518	0.2110	0.0063	Unequal	−1.206	0.228
		Female	373	0.4681	0.2306	0.0119	0.013		
	NSN	Male	1126	0.6120	0.2508	0.0075	Equal	0.191	0.849
		Female	373	0.6091	0.2538	0.0131	0.614		
	NRFC	Male	1126	0.4543	0.2648	0.0079	Equal	−0.265	0.791
		Female	373	0.4584	0.2611	0.0135	0.595		
	NTFC	Male	1126	0.4265	0.3262	0.0097	Equal	−1.327	0.185
		Female	373	0.4524	0.3278	0.0170	0.927		
Education	NHRMI	Lower	1047	0.5808	0.1925	0.0059	Unequal	−2.895	0.004
		Higher	452	0.6148	0.2149	0.0101	0.023		
	NPBACC	Lower	1047	0.6357	0.1712	0.0053	Equal	−3.807	0.000
		Higher	452	0.6733	0.1847	0.0087	0.101		
	NPSCC	Lower	1047	0.4367	0.2112	0.0065	Unequal	−5.173	0.000
		Higher	452	0.5002	0.2211	0.0104	0.008		
	NSN	Lower	1047	0.5987	0.2444	0.0076	Unequal	−2.860	0.004
		Higher	452	0.6404	0.2651	0.0125	0.003		
	NRFC	Lower	1047	0.4422	0.2545	0.0079	Unequal	−2.813	0.005
		Higher	452	0.4856	0.2822	0.0133	0.054		
	NTFC	Lower	1047	0.4260	0.3263	0.0101	Equal	−1.259	0.208
		Higher	452	0.4491	0.3274	0.0154	0.751		

Note: Test for equality of variances was firstly conducted to identify whether the variances between each group were equal or non-equal, and then an independent *t* test was conducted to for equality of Means; S.D. stands for standard deviation, S.E. stands for standard error.

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