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Promotion Policy Design for Climate-Adaptive Technology: Analysis Based on Discrete Choice Experiments

Yong Fu, Yuhang Li, and Hui Mao

This study investigates farmers' preferences for policies promoting climate adaptation strategies. The results indicate that farmers prefer policies including technology subsidies, technical training, and agricultural insurance. Furthermore, the analysis reveals significant complementarity effects between technology subsidies and technical training, technology subsidies and agricultural insurance, as well as agricultural insurance and agricultural production trusteeship. Conversely, substitution effects are observed between technical training and agricultural production trusteeship, as well as technical training and agricultural insurance. Farmers exposed to higher disaster severity prefer policies emphasizing agricultural insurance, while those with heightened risk perception are less inclined towards policies involving agricultural production trusteeship.

Key words: Climate adaptation strategies; Discrete Choice Experiment; Disaster Severity; Risk Perception; Mixed-Logit Model

Introduction

Climate change exerts far-reaching impacts on both natural systems and human livelihood, generating long-term adverse effects on economic growth (Mach et al., 2019; Meierrieks, 2021). It intensifies water shortages, reduces agricultural productivity (Ali et al., 2012), and threatens food security (Lee et al., 2024). Climate change exerts shocks on the financial system when it surpasses a certain threshold. Existing studies have investigated the impact of climate change on agricultural production, particularly through the perspective of rising temperatures. They consistently reveal significant negative impacts even with the implementation of long-term adaptation strategies (Burke and Emerick, 2016; Chen and Gong, 2021). These adverse effects impact agricultural production directly through extreme weather events, such as high temperatures

*Yong Fu (corresponding author, fuyong_fy@163.com) is a PHD student of agricultural economics in College of Economics and Management at Nanjing Agricultural University. Yuhang Li (li1072078003@163.com) is a master of agricultural economics in Northwest Institute of Historical Environment and Socio-Economic Development at Shaanxi Normal University. Hui Mao (maohui@snnu.edu.cn) is an assistant professor of agricultural economics in Northwest Institute of Historical Environment and Socio-Economic Development at Shaanxi Normal University.
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and heavy precipitation (Trilnick and Zilberman, 2021). They also act indirectly by influencing human health (Meierrieks, 2021) and labor migration (Huang et al., 2020).

Globally, extreme weather events, including droughts, floods, and heatwaves, have significantly impacted crop production, leading to a 9-10% decline in global grain output (Lesk et al., 2016). Consequently, a widespread international consensus has emerged regarding the integration of climate adaptation strategies into national development strategies. The Intergovernmental Panel on Climate Change (IPCC), in its Special Report on Climate Change and Land, emphasizes that climate change has increased the incidence of agricultural pests and diseases in certain areas and affected crop yields. The Chinese government has proactively implemented various measures to mitigate and adapt to this global issue. Notably, in 2020, China formulated the National Strategy for Adapting to Climate Change. This strategy aims to strengthen climate change monitoring, early warning and risk management, as well as to improve the adaptive ability of agriculture and other economic sectors. Despite these efforts, the current adoption rate of climate adaptation strategies in China remains relatively low (Cui and Xie, 2022). Therefore, it is imperative to further explore and promote effective adaptation strategies to mitigate the risks that climate change poses to agricultural production.

Climate adaptation strategies are the primary means for farmers to confront the challenges caused by climate change and sustain agricultural livelihoods. Such strategies include cultivating drought-resistant crops, optimizing planting schedules, implementing efficient irrigation systems, and improving land management practices (Maia et al., 2018). Farmers also mitigate extreme weather impacts through proactive monitoring of meteorological forecasts and early warning systems. Crop diversification has also been shown to strengthen agricultural resilience against climate variability (Khan et al., 2022). Beyond on-farm interventions, livelihood diversification through non-agricultural employment represents an alternative adaptation pathway (Van Wey and Vithayathil, 2013).

Previous researches have extensively examined farmers' climate adaptation behavior from three main perspectives. Firstly, studies have identified individual characteristics as key determinants of adaptation decisions (Martey and Kuwornu, 2021; He et al., 2023). Secondly, household attributes significantly influence farmers' adaptability to climate change (Wang et al., 2021; Mi et al., 2021). Thirdly, policy support shapes farmers' climate adaptation behavior. Technology subsidies (Fisher et al., 2014), technical training (Shikuku et al., 2019), and technology demonstrations (Goyal and Netessine, 2007) all affect farmers' climate adaptation behaviors. Government interventions are pivotal in farmers' adaptation to climate change (Braunschweiger and Ingold, 2023). Government services, including technology promotion and training, enable farmers to better understand and implement effective climate adaptation strategies (Saqib et al., 2025). However, merely incentivizing farmers' adoption of these strategies through subsidies not only increases financial burdens but also hampers policy efficiency improvements (Xie et al., 2018). By contrast, combining multiple promotion policies can effectively encourage farmers to adopt climate adaptation strategies. For instance, the government can simultaneously offer technical assistance and technology subsidies to incentivize farmers.

Discrete choice experiments (DCE) offer valuable insights into farmers' policy preferences and decision-making processes. These experiments can effectively predict the adoption rates of agricultural measures before long-term policies are implemented (Waldman and Richardson, 2018). Schulze et al. (2024) found that DCE have been applied globally to enhance agricultural environmental policy design. In North America, research primarily centers on protected area plans, while in Latin America, it focuses on the Payments for Ecosystem Services (PES). Research on Asia remains relatively limited, with existing studies primarily focusing on payments for ecosystem services to smallholder farmers in China or their participation in organic farming. There remains a gap regarding farmers' preferences for climate adaptation strategies promotion policies and the substitution or complementary effects between these policies. As a predominantly small-scale agricultural nation, China faces the pressing challenge of improving the adoption rate of climate adaptation strategy. This necessitates exploring diverse policy tools to encourage farmers' active engagement in these measures, thereby enhancing agricultural productivity. Apple cultivation, with its perennial nature and high specialization, makes apple farmers demonstrate an urgent need for climate adaptation strategies. This study focuses on apple farmers in Shaanxi Province, investigating how policy design and technology promotion can enhance their willingness and capacity to adopt climate adaptation strategies. It aims to provide theoretical foundations and policy recommendations for sustainable agricultural development.

How can a range of policy measures be designed to encourage farmers' active adaptation to climate change? This study surveyed 622 apple farmers in the main apple-producing areas of Shaanxi Province. Policies are categorized into four attributes: technology subsidies, technical training, agricultural insurance and agricultural production trusteeship. This study examines farmers' policy preferences and identified the substitution and complementary effects among policies through constructing a Mixed Logit model. The study also examines how risk perception and disaster severity influence these preferences.

Compared with previous research, this study makes novel contributions in the following three aspects. First, it advances beyond the prevailing analytical perspective in existing literature, which primarily assesses farmers' adoption behavior of climate adaptation strategies based on a singular policy. Instead, this study explores farmers' diverse policy preferences, thus enhancing the understanding of their climate-adaptive behavior. While existing studies often examine the effects of individual policies such as insurance or subsidies (Falco, 2014; Huang et al., 2015), they tend to neglect the combined effects of multiple measures. Diversified promotion policies of climate adaptation strategies can more effectively encourage strategies adoption among farmers. To address this gap, this study considers four policy attributions: technical training, technology subsidies, agricultural insurance, and agricultural production trusteeship. It develops a "cost-benefit-risk" framework grounded in technology adoption decision theory (Saha et al., 1994), employing DCE and the Mixed Logit model to quantitatively assess farmers' preferences regarding climate adaptation strategies promotion policies. Additionally, we respond to the research imbalance identified by Schulze et al. (2024), which predominantly covers North American and African contexts, by applying DCE to an Asian setting.

Second, this study investigates substitution or complementary effects among various climate adaptation strategies promotion policies. Unlike previous studies that focused on individual policies in isolation, this study simulates farmers' trade-off behaviors in realistic decision-making contexts. Four policy types—technology subsidies, technical training, agricultural insurance, and agricultural production trusteeship—are included in the choice set. The study not only assesses farmers' preferences for individual policies but also evaluates their choices under various policy combinations, thereby revealing policy interactions. The findings offer a scientific foundation for governments to develop diversified technology promotion strategies that better align with farmers' practical needs.

Finally, from the perspective of disaster severity and risk perception, this study explains the main reasons for the variations in farmers' preferences for different policies. Previous studies have overlooked the heterogeneity of preferences among different farmers for technology promotion policies. However, farmers' decision-making in response to climate change is influenced not only by policy frameworks but also by their disaster experiences and risk perceptions. This study identifies the heterogeneous determinants shaping farmers' preferences for climate adaptation strategies, providing insights for developing targeted policy interventions. Such differentiated approaches can better address diverse needs and enhance proactive climate adaptation strategies.

The following sections present the theoretical analysis. Section 3 introduces attributes and level selection. Section 4 describes sample selection, detailing the principles for selecting research areas, the sampling process, and the descriptive analysis of variables. Section 5 presents the main results. Section 6 provides the main conclusions and discussion.

Theoretical Framework

The Theoretical Framework of Each Policy

The Technology Adoption Theory provides a core framework for analyzing farmers' adoption behavior of climate adaptation strategies. It emphasizes that farmers' decisions to adopt new technologies are rational processes based on cost-benefit and risk trade-offs (Saha et al., 1994). When the expected net benefits of new technologies significantly exceed those of traditional technologies, and farmers have sufficient resources and risk tolerance, their willingness to adopt will significantly increase. Conversely, if the cost of new technologies is high, the benefits are delayed, or the risks exceed the acceptable thresholds, farmers tend to maintain traditional practices. Climate adaptation strategies, such as intelligent irrigation systems, often involve high initial costs, delayed effectiveness, and uncertain production risks (Falco, 2014), which can deter adoption without external support. The obstacles that farmers encounter in adopting climate adaptation strategies are multidimensional, encompassing economic, cognitive, social, and institutional factors.

Addressing a single obstacle, such as economic costs, proves insufficient to drive behavioral change. A comprehensive approach is needed to identify and intervene in all key barriers (IPCC, 2022). While individual policy tools, like subsidies, may mitigate specific obstacles, a combination of multiple policies is essential to overcome the diverse factors limiting farmers' adoption of climate adaptation strategies. Effective policy interventions can encourage behavioral change by lowering adoption costs, diversifying risks, and increasing expected returns. Building upon this theoretical framework, this study examines four policy instruments: technical training, technology subsidies, agricultural insurance, and agricultural production trusteeship. It investigates farmers' actual policy preferences and demonstrates how policy synergies influence learning costs, purchase expenses, risk expectations, and resource limitations, thereby facilitating the adoption of climate adaptation strategies. The specific analysis proceeds as follows:

(1) Technical training. Technical training effectively enhances farmers' understanding of advanced production techniques (Cui et al., 2022). In developing countries, where farmers' literacy remains low, traditional agricultural production methods persist and cognitive barriers hinder the adoption of advanced production technologies (Ammann et al., 2022). Technical training serves two main functions. First, it raises farmers' awareness of climate change, fostering the adoption of climate adaptation strategies. Second, it reduces uncertainty by addressing knowledge gaps in new technologies and reducing learning costs. Consequently, technical training significantly contributes to promoting the agricultural technologies adoption.

(2) Technology subsidies. Technology subsidies, a form of government transfer payment, aim to incentivize the adoption of new agricultural technologies. These subsidies serve to encourage farmers to adopt agricultural technologies with positive externalities by addressing key adoption barriers. Adoption costs are a primary concern for farmers (Huang et al., 2015). Technology subsidies play a crucial role in alleviating financial constraints faced by farmers, thereby reducing the costs of adopting new agricultural technologies (Falco, 2014). This financial support increases farmers' willingness to adopt new technologies. Additionally, subsidies mitigate the risks inherent in agricultural production by offsetting potential losses. By reducing such uncertainties, these subsidies enhance farmers' expected returns and further promote technology adoption.

(3) Agricultural insurance. Agricultural insurance incentivizes farmers to adopt new technologies. By mitigating the systemic risks inherent in agricultural operations (Farrin and Miranda, 2015), it enhances farmers' resilience and facilitates the adoption of climate adaptation strategies. Additionally, agricultural insurance optimizes resource allocation and stabilizes production expectations through risk diversification, driving higher production investment (Gunnsteinsson, 2020) and further encouraging climate adaptation strategies.

(4) Agricultural production trusteeship. The development of modern agriculture depends on digitizing the entire agricultural production process, with agricultural production trusteeship

acting as the intermediary between farmers and modern operations. Agricultural production trusteeship offers comprehensive, specialized, and large-scale services. As a kind of agricultural socialized service, it involves agricultural entities entrusting all or part of production processes—plowing, planting, pest control, and harvesting—to specialized service organizations or individuals, while retaining land management rights (Zhao et al., 2023). Driven by policy initiatives and market forces, China's agricultural socialized service organizations have expanded rapidly. From 2017 to 2020, the central government allocated 15.5 billion yuan to support these services, focusing on agricultural production trusteeship. By the end of 2021, the total area under agricultural production trusteeship in China reached 1.67 billion mu (1 mu ≈ 667m²), benefiting over 78 million small-scale farmers[1].

As a pioneer in agricultural production trusteeship, Shaanxi Province has achieved significant progress through policy support and subsidies. In 2020, it recorded 26,200 service entities managing 45.702 million acres across wheat, corn, rice, apples, kiwifruit, Sichuan pepper, and traditional Chinese medicine. Research indicates that agricultural production trusteeship improves production quality and efficiency while promoting agricultural technologies adoption (Sun et al., 2023). It optimizes resource allocation and improves agricultural productivity (Chamberlin and Ricker-Gilbert, 2016). Through technological advancements and factor substitution, it reduces production costs, increases yields, and enhances overall efficiency (Verkaart et al., 2017). It also facilitates the adoption of modern production technologies among small-scale farmers, contributing to the standardization and greening of agricultural practices. Compared to other agricultural production services, agricultural production trusteeship offers advanced technological equipment and advantages in economies of scale, specialization, and sustainability. The trusteeship organization also has scale effects of both horizontal and vertical multi-link services, significantly reducing the risks and costs of large-scale land management. Therefore, farmers participating in agricultural production trusteeship are more inclined to adopt climate adaptation strategies.

The Theoretical Framework of Policy Interaction

Agricultural support policies are key tools for enhancing farmers' resilience to external risks and increasing their incomes. China has implemented multi-dimensional support measures—such as technical training and direct subsidies—which has significantly advanced agricultural development and raised farmers' earnings. As noted, farmers encounter multiple barriers when adopting climate adaptation strategies, including high costs, limited knowledge and capacity, climate uncertainty, and resource constraints. Technology subsidies can ease financial burdens, training programs enhance operational skills, agricultural insurance reduces perceived climate risks, and agricultural production trusteeship alleviates resource shortages for smallholders. However, single-dimensional policies address only specific obstacles. Recognizing this limitation, all sectors of society have emphasized the importance of policy interaction (Rogge et al., 2020). Policy interaction refers to the combined impact of a policy when it is affected by the presence of other policies. Research in Australia shows that combining direct and indirect policies produces complementary effects, boosting inputs and improving production performance.

Multidimensional policy combinations systematically lower adoption thresholds through complementary effects, potentially increasing the marginal utility of interventions[2]. For example,

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[1] http://www.ghs.moa.gov.cn/xczx/202210/t20221021_6413824.htm

[2] Suihua City in Heilongjiang Province has actively implemented the "Policy-based Agricultural Insurance+" initiative, creating an integrated industrial chain that combines "Precision Insurance, Precision Subsidies, Precision Loans, and Precision Orders." This approach has facilitated resource consolidation and significantly enhanced agricultural productivity (http://fgw.panzhihua.gov.cn/zfxxgk/fdzdgknr/sjzq/dxal/10181152.shtml). The findings of this study offer valuable insights for refining current technology promotion strategies.

technology subsidies provide farmers with financial support and directly ease the economic burden of adopting new technologies. However, if farmers lack the necessary operational skills, the benefits of these subsidies may not translate into actual productivity. When combined with technical training, the training helps ensure that farmers adopt climate adaptation strategies effectively, and improved skills may enhance the efficiency of subsidy use. Additionally, agricultural production faces multiple risks, including climate and operational risks. A single risk protection policy is often insufficient. When agricultural insurance is combined with trusteeship services, it can reduce both natural and management-related risks, creating an effective risk-hedging mechanism. Therefore, this study designs various combinations of technology promotion policies for farmers to choose from and uses a DCE to quantify their preferences, providing evidence-based insights for developing effective climate adaptation strategies.

Attributes and levels selection

Prior to the formal experiment design, a pre-survey was conducted. Its design process and key findings are detailed in the sections titled "Design development" and "The Process and Findings of Pre-survey" within the Online Supplement. Building upon the insights from Chèze et al. (2020) and the findings of pre-survey, this study identified five attributes—technology subsidies, technical training, agricultural insurance, agricultural production trusteeship and technical requirements—for inclusion in the DCE. The attribute selection also took into account the characteristics of apple production and farmers. Detailed attribute specifications are outlined below:

Firstly, this study establishes technology subsidy options based on the farmland fertility protection subsidy standards in Shaanxi Province. In 2016, with the approval of the State Council, the central government implemented nationwide reforms that consolidated three agricultural subsidies into a single agricultural support and protection subsidy. These reforms integrated subsidies for high-quality crops, direct subsidies to grain farmer, and comprehensive agricultural input subsidies. The "three subsidies in one" reform pursues two main objectives: supporting the protection of arable land fertility and promoting moderate-scale grain operations. The subsidy for farmland fertility protection constitutes a universal benefit policy, providing financial support to contracted farmland holders who maintain land quality. It aims to reduce the usage of pesticide and fertilizer, improve crop straw utilization, and encourage water-efficient agricultural practices[3]. To enhance farmers' comprehension and ensure that the experimental design reflects real-world conditions, this study establishes technology subsidies options based on the subsidies for farmland fertility protection. Therefore, combined with practical factors in apple planting and following the subsidy standards of cultivated land fertility protection in Shaanxi Province, this study sets four levels of technology subsidy: 0, 25 yuan/mu, 50 yuan/mu, and 75 yuan/mu[4]. These options not only expand the subsidy standard from zero subsidies to amounts exceeding current standards, exploring the degree of incentives for farmers under different subsidy ranges, but also align with local governments' financial capacities while maintaining practical feasibility.

Secondly, agricultural technology training can reduce barriers to technology adoption by disseminating knowledge about climate adaptation strategies to farmers. This enhances farmers' comprehension of new technologies and encourages them to proactively adopt climate adaptation strategies. For example, field training can mitigate the risk of technical misuse by addressing practical operational requirements, including irrigation scheduling and water allocation. Accordingly, this study defines climate-adaptive technical training as three options: no training, field training, and indoor training. These options reflect the local government's existing training

[3] http://www.taonan.gov.cn/xxgk/zcjd/202312/t20231225_979404.html

[4] The special subsidy for water-saving irrigation technology in Shandong Province ranges from 30 to 80 yuan per mu (Lu Nong Ji Tui [2022] No. 5), which further confirms the feasibility of the option settings presented in this study.

framework and allow farmers to choose among distinct formats. They aim to identify farmers' true preferences for technical training methods, enabling technology promotion departments to adopt the most preferred approaches. This strategy seeks to boost farmers' engagement in technical training and ultimately strengthen their capacity to adapt to climate change.

Thirdly, policy agricultural insurance represents a form of agricultural insurance jointly subsidized by both the central and local governments in China. Its main goal is to assist farmers in mitigating agricultural production risks at a low cost. This not only increases farmers' agricultural income but also significantly increases non-agricultural income. Based on the pre-survey results related to agricultural insurance in the previous section, this study sets three options for agricultural insurance: no insurance, weather index insurance, and policy agricultural insurance. The design of this attribute reflects the differences in how various insurance types address climate change risks. This approach helps evaluate farmers' preferences for various insurance options and aligns with Shaanxi Province's policy goal of achieving comprehensive apple insurance coverage.

Moreover, as the primary entity in agricultural socialization services, agricultural production trusteeship uses high-tech and Internet of Things technology to provide farmers with full-chain services from production to sales. By integrating large-scale operations with supply and marketing, agricultural production trusteeship effectively reduces intermediary links and costs, thereby ensuring farmers' production and income. Consequently, this study examines two scenarios: agricultural production with trusteeship and without trusteeship. This comparative approach effectively demonstrates the feasibility and promotional potential of trusteeship services in practice and helps explore farmers' preferences for such services.

Finally, most DCEs contain cost attributes. These attributes allow the preference estimates for the four policy attributes to be converted into farmers' willingness to pay (Martinet et al., 2025). The levels assigned to the cost attribute form a cost vector. In actual decision-making, cost attributes influence farmers' policy preferences. The design of the cost attribute must be reasonable and credible, avoiding excessively high or low values, and should help farmers understand and make decisions quickly. Cost attributes are particularly important in DCEs focused on optimizing agricultural technology promotion policies, as farmers are the direct adopters of climate adaptation strategies. Their adoption decisions involve a cost-benefit trade-off. Only when farmers are able to adopt climate adaptation strategies under certain policy guarantees can the objectives of technology promotion policies be achieved.

Cost attributes include both monetary and non-monetary costs (Meginnis et al., 2020). This study uses non-monetary costs as cost attributes. By comparing the proportion of farmers willing to adopt climate adaptation strategies on their cultivated land under different policy combinations, this study can more intuitively assess farmers' preferences for these combinations. A higher adoption proportion under a specific policy combination indicates that farmers are willing to bear a higher cost, reflecting a stronger preference for that policy. Based on expert consultation and pre-survey results, this study set the attribute "proportion of cultivated land adopting climate adaptation strategies (water-saving irrigation technologies) under relevant technical guidance and services" at three levels: 20%, 50%, and 100%. This refers to the share of farmland on which farmers are willing to implement climate adaptation strategies under policy support, such as farmers applying such strategies to at least 50% of their land. This attribute effectively captures farmers' actual willingness to adopt climate adaptation strategies under different policy combinations. The attributes and levels are presented in Table 1:

This study uses fraction factorial design to determine 40 options for climate adaptation strategy promotion policies, and matches them according to the principle of attribute-level balance. These options were then randomly divided into 8 blocks. During the survey, each interviewed farmer randomly selected one block. Each block contains 5 choice sets. Each choice set consists of 3 options representing combinations of climate adaptation strategy promotion policy attributes and 1 option composing "choose nothing, maintain the status quo" (examples are

Table 1 Overview of Attributes

Attributes	Definition	Level
Technology subsidies	The government provides technology subsidies for climate adaptation strategies	0; 25 yuan/mu; 50 yuan/mu; 75 yuan/mu
Technical training	The government regularly provides technical training for climate adaptation strategies	No training; Field training; Indoor training
Agricultural insurance	Insurance for climate adaptation strategies	No insurance; Weather index insurance; Policy agricultural insurance
Agricultural production trusteeship	Agricultural production trusteeship	Yes; No
Technical requirements	Under promotion policies, the proportion of farmland where farmers adopt climate-adaptive technologies	20%；50%；100%

Table 2 Example of A Choice Card Used in the Choice Experiment

A1B1	A	B	C	D
Technology subsidies	75 yuan/mu	25 yuan/mu	0	
Technical training	Indoor training	No training	Field training	I prefer my current cropping practice
Agricultural insurance	Policy agricultural insurance	Weather index insurance	No insurance	
Agricultural production trusteeship	No	Yes	Yes	
Technical requirement	50%	20%	100%	
Choice				

shown in Table 2). Including a status quo option reduces bias in farmers' selections among options A, B, and C. If maintaining current practices provide greater utility than these alternatives, farmers may choose the status quo. Each farmer selected the most preferred attribute combination from the four options. If a farmer chooses Plan A, it is considered that Plan A offers higher expected utility than Plan B, C, and D. The specific attribute design process is detailed in the section titled "Attributes Design" within the Online Supplement.

Before conducting the DCE, the investigators provided farmers with a detailed explanation of each attribute. The differences between Plans A, B, C, and D were also clearly explained. A pre-experiment was conducted to clarify that the study aimed to promote the adoption of climate adaptation strategies. Once the farmers fully understood the meanings and purposes of each attribute and option selection, they were asked to choose their most preferred option in each choice set based on their actual agricultural conditions. Each respondent made five selections, concluding the experiment and yielding the necessary data.

Table 3 Summary Statistics

Definition	Mean	SD	Definition	Min	Max
ASC	Keep current=1; Participation in the technology promotion=0	0.250	0.433	0	1
Technology subsidies	1= No subsidies; 2=25 yuan/mu; 3=50 yuan/mu; 4=75 yuan/mu	2.127	1.167	1	4
Technical training	1= No training; 2= Field training; 3= Indoor training	1.750	0.829	1	3
Agricultural insurance	1=No insurance; 2=Weather index insurance; 3=Policy agricultural insurance	1.750	0.829	1	3
Agricultural production trusteeship	1=Yes; 2=No	1.356	0.479	1	2
Technical requirements	1=20%; 2=50%; 3=100%	1.750	0.829	1	3
Disaster severity	Accumulated value of disaster affected area in the past five years	29.59	30.68	0	480
Risk perceptions	Do you think the severity of the losses caused by the increase in temperature to production (1=not serious; 2=not too serious; 3=average; 4=relatively serious; 5=very serious)	3.096	1.266	1	5

Sample and Data

The data in this study were collected from a field survey conducted by our research team in Shaanxi Province, China, in November 2021. This study focuses on apple farmers in Shaanxi, as a representative sample, offering valuable insights for regions with comparable social, cultural, and agricultural conditions. Following randomized sampling principles, 650 respondents were selected from Fu County, Yichuan, and Luochuan in Yan'an City, alongside Baishui, Chengcheng, and Heyang counties in Weinan City. The sampling rationale and detailed procedures are documented in the section titled "Sample" within the Online Supplement.

The survey was conducted through face-to-face interviews. The data refer to the year 2021. In total, 650 apple farmers were interviewed (The principles for determining sample size are documented in the section titled "Principle of Determining Sample Size" within the Online Supplement.). After excluding questionnaires with missing variables, 622 valid questionnaires were obtained, with an effective rate of 95.69%[5].

This study defines the dependent variable as the farmers' choice of a certain plan. "Selected" is defined as 1, otherwise 0. In the model, the status quo constant (ASC) is set to 1 for option D (Farmers make no changes and maintain the current farming methods) in the choice set. For the other options, the values are set to 0. The core independent variables include five attributes: technology subsidies, technical training, agricultural insurance, agricultural production trusteeship and technical requirements. Table 3 presents the variable definitions and descriptive statistics.

[5] The questionnaire comprises a discrete choice experiment on climate adaptation technologies, alongside modules capturing farmers' basic characteristics, land use patterns, household credit profiles, income-expenditure structures, apple production and marketing dynamics, and meteorological disaster experiences. The questionnaire is listed in Appendix IV.

Table 4 Baseline Results

Variables	(1) Mixed Logit Mean	(2) Mixed Logit Std. Dev.	(3) C-logit	(4) Mixed Logit Mean	(5) Mixed Logit Std. Dev.	(6) C-logit
ASC	-1.926***		-1.706***	-	-	-
	(0.232)		(0.126)	-	-	-
Technology subsidies	0.238***	0.386***	0.190***	0.226***		0.190***
	(0.028)	(0.062)	(0.017)	(0.023)		(0.017)
Technical training	0.085***	-0.019	0.049**	0.080***	0.002	0.048**
	(0.024)	(0.027)	(0.019)	(0.022)	(0.006)	(0.019)
Agricultural insurance	0.215***	0.738***	0.187***	0.247***	0.552***	0.185***
	(0.043)	(0.062)	(0.023)	(0.038)	(0.048)	(0.023)
Agricultural production trusteeship	-0.409***	0.829***	-0.314***	-0.368***	-0.663***	-0.313***
	(0.062)	(0.104)	(0.041)	(0.055)	(0.084)	(0.041)
Technical requirements	0.493***	0.833***	0.365***	0.487***	0.711***	0.363***
	(0.051)	(0.073)	(0.025)	(0.046)	(0.058)	(0.025)
Observation	12440			9087		
log likelihood	-3240.102		-3457.311	-2960.524		-3082.428
LR Chi2	344.49***		981.18***	263.06***		444.19***

Note: ***, **, * indicates that the estimated result is significant at the level of 1%, 5%, 10%. The numbers in parentheses are standard errors.

Results

Baseline results

This study uses the Mixed-Logit model to estimate the baseline results, with the results shown in Columns (1)-(2) in Table 4. The results reveals that the parameter value of ASC is significantly negative at the 1% level. This indicates that farmers tend to adopt climate adaptation strategies, suggesting that such adoption significantly enhances farmers' utility. The coefficients of technology subsidies, technical training and agricultural insurance are significantly positive at the 1% level. This implies that, when adopting new technologies, farmers value the potential increase in production costs. Technology subsidies can reduce technology adoption costs, alleviate financial constraints, and encourage farmers' adoption of climate adaptation strategies. Technical training enhances farmers' awareness of climate adaptation strategies through information transfer and improves their adoption of climate adaptation strategies. Furthermore, agricultural insurance with risk diversification functions can significantly improve farmers' technology adoption utility.

The coefficient of agricultural production trusteeship is significantly negative (-0.409) at the 1% level, indicating that agricultural production trusteeship substantially reduces the utility of adopting climate adaptation strategies for apple farmers, which is contrary to expectations. This is because agricultural production trusteeship involves principal-agent relationships, encompassing external risks and systemic risks in agricultural production. As most farmers are risk-averse, this psychology impedes farmers' participation in agricultural production trusteeship.

Additionally, barriers to trust emerge due to market information asymmetry. Farmers' doubts arise regarding whether agricultural production trusteeship can truly improve agricultural outcomes, leading to low willingness to participate in agricultural production trusteeship. Field surveys also reveal that when the government provides technology subsidies, technical training and agricultural insurance, farmers are more willing to adopt climate adaptation strategies. However, due to limited non-agricultural employment opportunities in the surveyed area and the scarcity of trusteeship providers, farmers lack understanding of agricultural production trusteeship and show insufficient trust in trusteeship providers, resulting in a low willingness to participate in agricultural production trusteeship.

Except for technical training, the standard deviations of the parameters for the other four attributes are all significant at the 1% level. This suggests that farmers show heterogeneous preferences for the four attribute variables: technology subsidies, agricultural insurance, agricultural production trusteeship, and technical requirements. In addition, this study uses the C-logit model to assess the robustness of the results, as shown in Column (3) in Table 4. The findings are basically consistent with those of the mixed logit model, indicating that the baseline results are robust. To further assess the robustness of the baseline results, this study conducts an analysis by removing the ASC from the sample. The results are shown in Columns (4)-(6) in Table 4. After excluding the ASC, all policy attribute variables remain significant at the 1% level, and the results closely align with those in Columns (1)-(3). Consequently, the baseline results are robust.

Substitution or complementary effects between different policy attributes

To further examine the complementarity and substitutability among various climate adaptation strategy promotion policies, this study adds interaction terms of policy attributes to the baseline model. The results are shown in Table 5. Analyzing the coefficients of the interaction terms, it is observed that the coefficients for the interactions between technology subsidies and technical training, as well as between technology subsidies and agricultural insurance, are significantly positive at the 10% and 5% levels respectively. This indicates a complementary effect between technology subsidies and technical training, as well as between technology subsidies and agricultural insurance. Farmers show a preference for diversified climate adaptation strategy promotion policies. Therefore, when promoting climate adaptation strategies, technical training needs to be paired with technology subsidies to provide economic incentives to farmers, enhance the effectiveness of technology promotion, and encourage farmers to adopt climate adaptation strategies. Simultaneously, technology subsidies should be supported by agricultural insurance. As a risk diversification tool, agricultural insurance can mitigate the uncertainty in farmers' technology adoption, indicating a complementary effect between technology subsidies and agricultural insurance.

Furthermore, the coefficients of the interaction terms between technical training and agricultural insurance, and between technical training and agricultural production trusteeship, are significantly negative at the 10% and 1% levels, respectively. This implies significant substitution effects between technical training and agricultural insurance, as well as between technical training and agricultural production trusteeship. Through technical training, farmers gain knowledge and skills in new technologies, and enhance their capabilities in agricultural production and management, thereby reducing the uncertainty in agricultural practices. As a result, with the acquisition of advanced agricultural information, farmers may lower their demand for agricultural production trusteeship. Lastly, the coefficient of the interaction term between agricultural insurance and agricultural production trusteeship is significantly positive at the 5% level, indicating a significant complementary effect. The increase in agricultural insurance reduces farmers' risk perceptions and enhances their willingness to participate in agricultural production trusteeship.

Table 5 The Result of Substitution or Complementary Effects Between Different Policy Attributes

Variables	Interaction Item Model	
	Mean	Std. Dev.
ASC	-2.791***	
	(0.260)	
Technology subsidies	-0.037	0.538***
	(0.176)	(0.051)
Technical training	-0.354**	0.020
	(0.147)	(0.029)
Agricultural insurance	-0.106	0.692***
	(0.143)	(0.057)
Agricultural production trusteeship	0.472*	-0.612***
	(0.262)	(0.099)
Technology subsidies *Technical training	0.073*	
	(0.038)	
Technology subsidies *Agricultural insurance	0.076**	
	(0.036)	
Technology subsidies *Agricultural production trusteeship	-0.035	
	(0.058)	
Technical training*Agricultural insurance	-0.152*	
	(0.080)	
Technical training*Agricultural production trusteeship	-0.259***	
	(0.063)	
Agricultural insurance*Agricultural production trusteeship	0.076**	
	(0.036)	
Observation	12440	
log likelihood	-3419.3328	
LR Chi2	359.75***	

Note: ***, **, * indicates that the estimated result is significant at the level of 1%, 5%, 10%. The numbers in parentheses are standard errors.

The heterogeneity analysis of disaster severity

Natural disasters resulting from climate change can reduce crop yields, and disaster severity may influence farmers' inclination for technology adoption. To further investigate the impact of the disaster severity on farmers' policy preference for climate adaptation strategies, this study introduces the disaster severity into the baseline model (The measurement of disaster severity is detailed in the section of “The measurement of disaster severity” in Online Supplement.). The results are shown in Column (1) in Table 6. The results show that the interaction between technical requirements and disaster severity is significantly positive at the 10% level. This suggests that as the disaster severity increases, farmers are more inclined to adopt climate adaptation strategies to stabilize production and secure income. The interaction between disaster severity and agricultural insurance is significantly positive at the 1% level. This implies that farmers facing more severe disasters have higher demand for agricultural insurance. The reason for this result is that agricultural insurance can improve farmers' resilience to production risks, stimulates increased investment in agricultural inputs, and reduces agricultural losses. As disaster severity intensifies, farmers actively increase their investment in agricultural insurance to ensure returns. Therefore, when promoting climate adaptation strategies to farmers frequently affected by disasters, combining them with corresponding agricultural insurance significantly improves the effectiveness of technology adoption.

The heterogeneity analysis of risk perception

Risk perception significantly influences farmers’ risk-related decision-making. Farmers with stronger risk perceptions may be more willing to adopt climate adaptation strategies. This study introduces interaction terms between risk perception and each attribute to the baseline model to examine the impact of risk perception on farmers' preferences for climate adaptation strategy promotion policies (The measurement of risk perception is detailed in the section of “The measurement of risk perception” in Online Supplement.). The results are detailed in Column (2) of Table 6. It is evident that the interaction term between agricultural production trusteeship and risk perception, as well as the between technical requirements and risk perception, are significant. The coefficient of the interaction between risk perception and technical requirements is significantly positive at the 10% level. This suggests that farmers with high-risk perception show a stronger willingness to adopt climate adaptation strategies. Farmers with stronger risk perception are more sensitive to agricultural risks stemming from climate change and are more inclined to adopt climate adaptation strategy.

The coefficient of the interaction between agricultural production trusteeship and risk perception is significantly negative (-0.104) at the 5% level, signifying that farmers with higher risk perceptions are less willing to participate in climate adaptation strategy promotion policies involving agricultural production trusteeship. Agricultural production trusteeship can reduce planting costs and resource constraints through technological advancements and factor substitution, thereby enhancing agricultural productivity and fostering high-quality agricultural development (Verkaart et al., 2017). However, farmers encounter certain risks when opting for agricultural production trusteeship. One major risk stem from natural uncertainties. The ability of service providers to ensure crop yields depends on the absence of natural risks, which are inherently unpredictable.

When such risks occur, determining liability for losses becomes challenging, often leading to disputes over compensation between farmers and service providers. Moreover, agricultural production trusteeship involves service fees, increasing the cost of agricultural operations. As a result, farmers with a heightened perception of climate risks are more inclined to rely on their own strategies to mitigate climate-related disasters, adjusting their practices promptly to minimize losses rather than choosing trusteeship services. Furthermore, agricultural production trusteeship

Table 6 The Result of the Interaction with Disaster Severity

Variables	Interaction with Disaster Severity	Interaction with Risk Perceptions
	(1)	(2)
ASC	-1.923***	
	(0.231)	
Technology subsidies*disaster severity	-0.001	
	(0.001)	
Technical training*disaster severity	-0.001	
	(0.001)	
Agricultural insurance*disaster severity	0.005***	
	(0.002)	
Agricultural production trusteeship*disaster severity	0.000	
	(0.002)	
Technical requirement*disaster severity	0.003*	
	(0.002)	
Technology subsidies*risk perceptions		-0.016
		(0.022)
Technical training*risk perceptions		-0.003
		(0.019)
Agricultural insurance*risk perceptions		0.005
		(0.034)
Agricultural production trusteeship*risk perceptions		-0.104**
		(0.050)
Technical requirement*risk perceptions		0.061*
		(0.037)
All attributes	Yes	Yes
Observation	12440	
log likelihood	-3233.751	-3068.7266
LR Chi2	379.42***	308.09***

Note: ***, **, * indicates that the estimated result is significant at the level of 1%, 5%, 10%. The numbers in parentheses are standard errors.

creates a contractual relationship between farmers and service providers, which is susceptible to moral hazard, as evidenced by both theoretical and empirical studies. While service providers offer specialized services, they may also act opportunistically. Non-compliance with contractual terms can result in significant losses for farmers. Additionally, trusteeship carries implicit risks of default. For instance, excessive land use or alterations in land use decisions by service providers can adversely affect the long-term interests of farmers. Consequently, farmers with higher risk perceptions are more willing to manage production themselves and show less enthusiasm for agricultural production trusteeship.

In addition, it is noteworthy that we have expanded the analysis to include factors such as farm scale, household income, credit accessibility, and the educational attainment of the household head. Detailed results can be found in "Additional Analysis" in Online Supplement.

Conclusions and discussion

Based on the survey data of apple farmers in 2021, this study uses the DCE to explore farmers' preferences for different climate adaptation strategy promotion policies. Specifically, it measures farmers' preferences for policy attributes such as technology subsidies, technical training, agricultural insurance, and agricultural production trusteeship. The study further analyzes the substitution and complementarity effects among these policies. The main findings are as follows. First, farmers show a preference for climate adaptation strategy promotion policies that include technology subsidies, technical training, and agricultural insurance. However, their willingness to engage in policies involving agricultural production trusteeship is notably lower. Second, notable complementary effects are observed between technology subsidies and technical training, technology subsidies and agricultural insurance, and agricultural insurance and agricultural production trusteeship. Substantial substitution effects are found between technical training and agricultural production trusteeship, as well as between technical training and agricultural insurance. Third, farmers’ preferences for climate adaptation strategy promotion policies vary based on disaster severity and risk perception. Farmers more severely affected by disasters and those with stronger risk perceptions are more inclined to adopt climate adaptation strategy. Moreover, farmers' demand for agricultural insurance increases with disaster severity, while farmers with stronger risk perceptions are less willing to participate in policies involving agricultural production trusteeship.

These findings not only explain farmers' policy preferences for adopting climate adaptation strategies, but also confirm the substitution and complementarity effects among policies, providing valuable insights for the effective promotion of such strategies. Firstly, it is essential for the government to fully recognize the pivotal roles of technology subsidies, technical training, and agricultural insurance in promoting climate adaptation strategy. Developing scientifically grounded and rational policies will help stimulate farmers' participation enthusiasm. Secondly, policymakers need to account for the complementarity and substitution effects between policies, emphasizing a comprehensive policy mix. Instead of solely relying on economic incentives, it is essential to balance income stability for farmers and aligning policies with local conditions. While prioritizing technology subsidies, equal attention should be given to the supportive roles of technical training and agricultural insurance to foster effective synergy between policies and avoid conflicts that may impede technology adoption efficiency. Finally, addressing individual policy preferences, considering practical influences on farmers' decision-making, and implementing differentiated policies will contribute to establishing a long-term promotion mechanism. Combined with awareness-building efforts and professional training on climate adaptation strategies, these efforts can improve farmers' understanding and boost climate adaptation strategy adoption.

Climate change is complex and region-specific. Farmers in different areas adopt varied measures to cope with its impacts, and significant regional differences exist in government policies promoting climate adaptation. Apples are a perennial crop requiring complex agronomic practices and highly specific investment. Shaanxi Province, as the most important apple production base in China, has experienced substantial impacts from climate change. Thus, it serves as a typical case of asset-specific agricultural production in adapting to climate change, strengthening the argument of this study. This study selects two major apple-producing areas in

Shaanxi Province as case studies and conducts an in-depth analysis of apple growers' preferences for climate adaptation promotion policies. The findings not only offer a theoretical reference for future research on climate adaptation behavior but also provide a practical case reference for climate response in similar regions.

However, this study has certain limitations. First, due to data constraints, this study is limited to assessing disaster severity. While there is a notable disparity in disaster intensity in the research area, prioritizing disaster types based on regional correlations could enhance the differentiation of severity characteristics. Furthermore, the measurement of risk perception is somewhat subjective. Future research could achieve greater accuracy by adopting more objective methods to assess risk perception. Second, this study examines the origins of variations in farmers' policy preferences for climate adaptation strategy promotion by considering two factors: disaster severity and risk perception. However, the determinants of farmers' policy preferences could be more complex. Therefore, future research should investigate these additional factors in greater depth.

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