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Understanding herder's perception and adaptation to climate change: an integrated framework

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Abstract

Understanding the motivation and mechanism of adaptation among herdsmen is crucial for climate change research because it can provide insights into the social and ecological impacts of climate change, as well as the potential responses and strategies for mitigation and adaptation. This study investigates how rational and perceptual considerations of climate change influence individual adaptation behavior using an integrated framework based on the theory of planned behavior (TPB) and the protection motivation theory (PMT), as well as climate experience. We conducted a survey among 828 herder households in six counties within the Inner Mongolia Autonomous Region and Gansu Province in China and identified mutual correlations among TPB and PMT constructs, as well as climate-related experiences. Adaptation behaviors are shaped by a process that involves 'threat perception, rational judgment based on planned experiences, coping perception, and adaptation behavior' which encompasses both rational and empirical aspects. The perceptual knowledge of herders is gained through rational judgments, which are critical aspects of the adaptation process that can affect rationality and perceptual psychological cognition. Our findings show that climate experience has a more significant effect on climate adaptation behavior than other factors. Additionally, our structural equation modeling confirms the necessity and importance of the integrated framework. This research has significant implications for developing policies that promote climate change adaptation in pastoral areas and for advancing the theoretical framework of adaptation behavior research.

Keywords Climate change · Adaptation behavior · Protection motivation theory · Theory of planned behavior · Herdsmen

1 Introduction

Climate change had a significant impact on China, particularly on its livestock industry. The country has experienced a range of extreme weather events and environmental changes that have had consequences for agriculture and livestock (Maxwell, 2011; Su et al., 2013). For instance, 76% of the total area of Inner Mongolia affected by natural disasters in 2016 was

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due to a severe drought that affected about 2,770,500 hectares of land. Subsequent wind and hail storms, floods, and freezing temperatures led to economic losses of 11.59 billion yuan. Various models and theories have been designed to understand the internal processes and predictors of climate adaptation behavior. Two such theories, the Theory of Planned Behavior (TPB) (Yadav & Pathak, 2017; Ma et al., 2018; Zhang et al., 2020) and the Protection Motivation Theory (PMT) (Dang et al., 2014; Tikir & Lehmann, 2011) are central to our analysis. The TPB is a social cognition theory that highlights the decision-making mechanisms and individualistic processes involved in making rational choices, proposing that individuals consider relevant information before making decisions and taking action (Rashidian & Russell, 2012). On the other hand, PMT focuses on an individual's perceived risk, perceived efficacy, and beliefs related to coping with threats, offering a valuable perspective on the motivation for adaptive behavior in the face of climate change.

By integrating TPB and PMT, this study aims to offer a comprehensive framework to understand herders' perceptions and adaptations to climate change, particularly emphasizing the context of livestock management in China. This integrated approach helps us explore how herders in the region process information, assess risks, and make decisions regarding climate adaptation strategies. The research studies suggest that participation in river basin ecological compensation is a rational behavior that can be influenced by factors such as available resources. However, the TPB model has been criticized for its limited consideration of adaptive motivation (Kloeckner & Bloebaum, 2010). Researchers tried to improve TPB models by introducing new measurement variables, such as environmental assessment (Echegaray & Hansstein, 2016), personal experience (Lam & Hsu, 2006; Oztekin et al., 2017), awareness of consequences, and moral norms (Abrahamse et al., 2009; Wan et al., 2017), as well as perceived value and residual effects (Cai et al., 2019). Nonetheless, all TPB variables remain rooted in the rational choice framework, evaluating pro-environmental behavior as a result of individual cost-benefit analysis.

Psychological factors have a significant impact on decision-making, beyond the traditional rational evaluation process (Bradley et al., 2020; Dang et al., 2012). Cai et al. (2023) pointed out that collective emotions hinder herder's participation, showing a "free-ride" metality. Understanding and personal relevance can be particularly challenging when dealing with climate change due to its complex nature, unpredictability, global impact, and long-term implications (Luccioni et al., 2021). Therefore, the perceptual process and motivation for adaptive behavior may differ from typical pro-environmental actions. The Theory of Planned Behavior (TPB) predicts future planned actions while the Protection Motivation Theory (PMT) takes into account an individual's perceived risk, perceived efficacy, and beliefs related to coping with threats. In addition, PMT serves as a valuable framework for understanding individuals' intentions to adapt to climate change by focusing on two critical perceptual processes: perceiving the risks associated with climate change and evaluating the effectiveness of adaptive measures (Dang et al., 2012).

Climate change adaptation involves efforts to minimize vulnerabilities to climate change impacts, enhance the capacity to implement alternative mitigation choice and address unforeseen challenges. Herdsmen use various adaptation strategies such as increasing forage storage, constructing greenhouses, selecting drought-resistant livestock breeds, implementing grazing rotations, renting pastures, optimizing pasture utilization, and relocating livestock (Jin et al., 2014; Zhang & Ai, 2018). These strategies can help herders counter the adverse effects of climate change and reduce their vulnerability When considering the specific context of herders in China, it becomes clear that the integration of TPB and PMT offers a more nuanced understanding of how herders perceive and respond to challenges posed by climate change. However, Jin et al. (2014) found a lack of initiative to adapt to climate change. It is widely acknowledged that psychological perceptions play a significant role in understanding individual decision-making processes, extending beyond conventional rational assessments (Dang et al., 2012). The Theory of Planned Behavior (TPB) predicts planned actions, while the Protection Motivation Theory (PMT) accounts for perceived risk, perceived efficacy, and threat-related coping beliefs.

The PMT serves as a conceptual framework for recognizing the risks associated with climate change and evaluating the effectiveness of adaptive measures (Dang et al., 2012). This theory is regarded as a useful tool for explaining pro-environmental behaviors and decisions related to risk, including climate change adaptation choices (Deressa et al., 2010; Fu et al. 2019; Shi et al., 2017; Ghazali et al., 2021; Schwaller et al., 2020), flood risk management and mitigation (Dittrich et al., 2016; Seebauer & Babcicky, 2021; Williams et al., 2020), water scarcity (Pakmehr et al., 2020), and agricultural practices such as willingness to participate in the ecosystem compensation (Zhang et al., 2019a), and straw return (Shi et al., 2019; Zhang et al., 2019a, 2019b).

Researchers have combined the TPB and the PMT to investigate various individual behaviors, such as reducing meat consumption, controlling non-point source pollution, and promoting sustainable environmental practices among farmers (Badsar et al., 2022; Chen, 2022; Wang et al., 2019). Their findings indicate that the integrated framework provides more comprehensive insights into the motivations behind these behaviors compared to when the theories are applied individually. The application of the integrated TPB and PMT framework to assess adaptive behaviors is particularly inadequate among Chinese herdsman households, who manage animal husbandry independently. These households heavily rely on animal husbandry, a practice intrinsically linked to the growth of grasslands, for their livelihoods. This process is highly sensitive to temperature and rainfall, even when artificial restoration techniques are employed. Consequently, the adaptation behaviors of these herdsmen expose them not only to climate-related risks but also to the possibility of losing their livelihoods, ultimately leading to a greater dependence on income as a rational choice. Moreover, previous studies on climate change adaptation behavior often overlooked the rational and perceptual factors influencing these behaviors, which is essential for mobilizing the herdsmen's intrinsic and initiative adaptation to climate change. Therefore, there is an urgent need for a more comprehensive framework in climate adaptation research that integrates cognitive, socio-psychological, and behavioral aspects, particularly in pastoral regions of developing countries, which often struggle with poor institutional capacity and high-income dependence (Masud et al., 2016).

Hence, it is imperative to assess and compare the value of the Theory of Planned Behavior (TPB) and the Protection Motivation Theory (PMT) in different contexts. These theories have unique implications for the study samples used in this research. TPB is conventionally considered a theory based on rational decision-making, while PMT emphasizes the perception of risk and coping processes. This approach is essential for understanding the dynamic relationship between herders' adaptation to climate change, specifically in livestock management and resource allocation, and their realities, perceptions, and rational judgments regarding climate threats. Individual experiences of climate-related events significantly affect attitudes and behaviors, serving as a powerful tool in determining an individual's intention to undertake preventive measures (Spence et al., 2011). By shedding light on diverse individual experiences, it becomes possible to attain a more comprehensive perspective on climate change adaptation (Broomell et al., 2015).

To deepen our understanding of climate adaptation behaviors among herders, the current study has three main objectives Firstly, it aims to analyze the factors that influence the climate adaptation behavior of herders in both TPB and PMT. Secondly, it establishes a comprehensive framework that integrates TPB, PMT, and climate experience to understand climate adaptation behavior better. Thirdly, it examines the relationships among the different constructs of this integrated framework, especially how cognitive and affective factors influence adaptation and interact with each other. Finally, it is the first empirical analysis that explores and compares the model suitability among the TPB, PMT, and integrated models in relation to climate change adaptation decision-making in the northern pastoral regions of China.

The paper is organized as follows: Sect. 2 reviews the theoretical background and proposes the study hypotheses. Section 3 tests the hypotheses using structural equation modeling and data from a survey of herders in Inner Mongolia and Gansu. Section 4 reports and discusses the results of the integrated model. Section 5 summarizes the main findings, and Sect. 6 provides practical implications and suggestions for climate change adaptation.

2 Theoretical background

The study of rationality in social psychology focuses on the nature of values and their changes; the process; the strategies for reasoning about complex realities; and how irrational processes such as motivation or emotion influence rational processes (Simon, 1987). Individuals' adaptation to climate change appears to be a risk management decision-making process under uncertain conditions. Under uncertain risk conditions, rational calculation and management can mitigate the negative consequences and losses of climate change on individual production and life. Understanding the perspectives, attitudes, and beliefs of the public regarding climate change is an important factor in climate adaptation process, which also represents an instrumental rationality aspect in the climate adaptation and mitigation processes (Leiserowitz et al., 2015). Some "systematic departures from rationality" have been proposed by researchers despite the traditional economic assumption that people are rational in their subjective judgments under uncertainty.

The perception of external risk and an individual's cognition of behavior ability reflect the role of perceptual factors in climate adaptation decision-making. However, most of the research on adaptive behavior lacks systematic theoretical guidance combining both rationality and sensibility. The occurrence of internal psychological mechanisms is uncertain. As Simon (1986) mentioned, the rational person makes decisions in a manner that is procedurally reasonable in the light of the available information and means of computation. However, subjective perceptions are more reliable predictors of behavior and decision-making, and they provide a better explanation for the irrational behavior resulting from cognitive aberrations (Sun et al., 2020). Therefore, what's the primary motivation for herders to adapt to climate change, and to what extent they are keen to engage in an active climate adaptation manner? It is necessary to examine the role of rational and perceptual factors in their motivation.

TPB and PMT are both used to explain individual behaviors and have their origins in health-related behavior studies (Rogers, 1975; Weinstein, 1993). From rational perspective, TPB primarily focuses on the relationship between an individual's ideas and opinions and their likelihood of engaging in certain activities. PMT explicitly separates the perceived cost and return factor of performing a new protective behavior from the perceived self-efficacy and the loss for performing this response, and primarily focuses on understanding how individuals respond to a threat based on their ability to manage the threat (Schwaller et al., 2020). Based on the above theories, both rational and perceptual factors have been fitted logically together in the integrated framework of combining TPB and PMT to deal with an individual's adaptive behavior to climate change.

2.1 The theory of planned behavior

The idea of Reasoned Action (TRA) provides theoretical foundation for the commonly used theory of planned behavior in the study of human behavior. As such, TPB assumes that individuals make reasonable decisions to engage in a specific behavior based on a set of theoretical constructs, including attitudes, subjective norms, and behavioral intention (see Fig. 1) (Ajzen & Fishbein, 1980; Zhang et al., 2020). (i) Attitudes towards certain behaviors, are influenced by an individual's beliefs about outcomes derived from performing the behavior and are identified as an evaluative response reflecting beliefs about the behavior (Montano & Kasprzyk, 2015); (ii) Subjective norms, which are affected by a person's motivations to adhere to the norms, quantify felt social pressure to engage in certain activities, and show whether an individual would accept responsibility for executing actions in response to external opinions that influence their actions (Albarracín et al., 2001); (iii) Perceived behavioral control, refers to an individual's perception of the occurrence of facilitators or barriers during the performance of a certain behavior, weighted based on their perception of the strength of each facilitator or barrier (Montano & Kasprzyk, 2015).

The theory of planned behavior represents an extension of the theory of reasoned action by including perceived behavioral control as a determinant of intention. According to TPB,

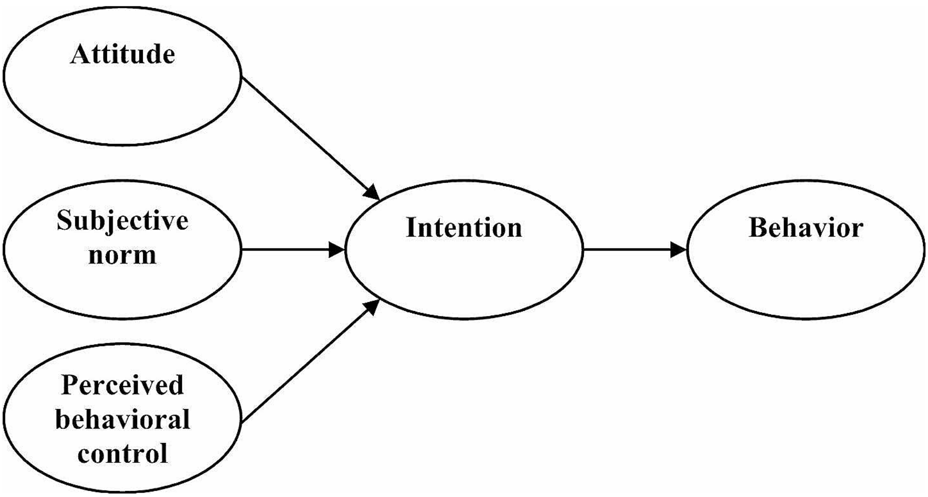

Fig. 1 Analysis framework based on the theory of planned behavior (Adopted from Masud et al. (2016)

attitude, subjective norm, and perceived behavioral control are all predictors of behavioral intention. In turn, behavioral intention, together with perceived behavioral control, can be used to predict behavior (Ajzen, 1991). Thus, this theory has been applied to comprehend adaptation to climate change and its proposed structure has been verified by previous studies (Tikir & Lehmann, 2011).

2.2 Protection motivation theory

Protection Motivation Theory (PMT), is commonly used as social cognitive basis models to examine the individual adaptive behavior in the fields of medical health, natural disasters, and environmental protection (Dang et al., 2018; Wang & Wang, 2013). It provides a systematic framework to explore the role of psychological factors in determining individual behavior in response to threat. The PMT theoretical framework provides a complete introduction of perceptual mediators to explain the intrinsic motivation of individual adaptive behavior shifts by incorporating social cognitive attributes, experiential habits, risk perception factors, and coping evaluations related to willingness to adopt in risky situations while taking into account individual threat perceptions and coping perceptions of non-adaptive behaviors and provides a mechanism and internal logic for studying the occurrence of climate change perceptions and adaptive behaviors of herdsmen.

The Protection Motivation Theory framework consists of three components: information sources, perceptual mediation processes, and coping behavior (see Fig. 2). As defined by Rogers (1975), the protection motivation theory is used to measure individuals' coping behaviors in the face of risky events, emphasizing the importance of cognitive activities for behavior change and the trade-off between gains and losses during behavior occurrence, i.e., it includes the cognitive process theory and the expectancy value theory. This theory suggests that individuals form two main perceptual adjustment processes, namely threat perception (risk perception) and coping perception (response perception), by judging the information transmitted by the external environment as well as their existing attributes and previous experiences with similar threats, and that the two processes interact with each other and eventually contribute to the occurrence of behavior with the motivation of self-protection (at this point, behavior includes both coping and non-coping behavior). Threat perception is the individual's comprehensive assessment of the threat faced, including factors that may lead to the emergence of adverse behaviors (return factor) and two factors that may inhibit the emergence of adverse behaviors (risk probability perception and risk loss perception, i.e., vulnerability and severity). The return factor, or rewards, is associated with current practices that may impede risk-protective actions or adaptive behavior. This construct encompasses all perceived benefits of current behavior or practice, which can be categorized as intrinsic (related to the self) or extrinsic (external) benefits (Bockarjova & Steg, 2014). Although some scholars argue that the conceptual distinction between the reward value of a risk behavior and the cost of a preventative measure may be unclear (Abraham et al., 1994), and thus rewards are rarely considered in PMT (Norman et al., 2015; Rainear & Christensen, 2017), a study of novice drivers' risk-driving behavior found that rewards and self-efficacy had the strongest explanatory power for their behavioral intention (Yang et al., 2019). Furthermore, a study on electric vehicle adoption based on PMT revealed two major barriers to adaptive behavior that are crucial to individual decision-making: the higher perceived monetary, functional, and symbolic rewards associated with conventional vehicles,

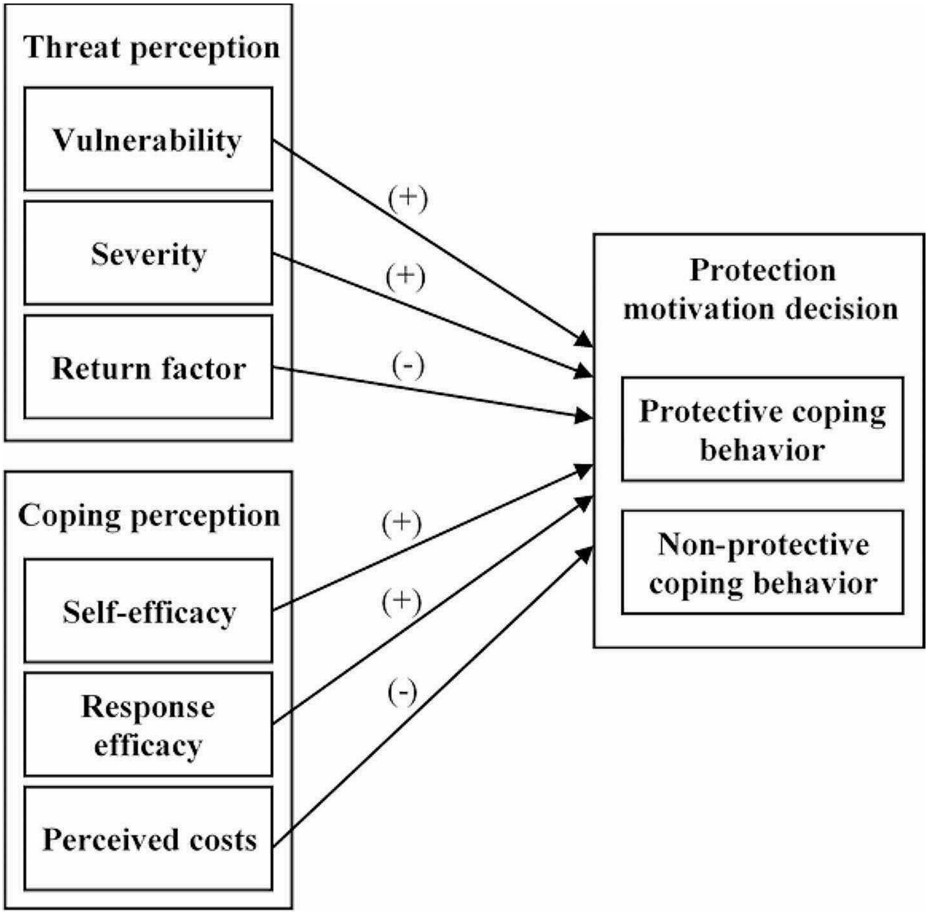

Fig. 2 Analysis framework based on the Protection Motivation Theory (Adopted from (Bockarjova & Steg, 2014)

and the higher perceived monetary and non-monetary costs of electric vehicles that hinder their adoption by Dutch drivers (Bockarjova & Steg, 2014). These findings suggest that we should follow the original version of the model by Rogers, which included six constructs. Coping perceptions include perceived costs, response efficacy, and self-efficacy. Of these, vulnerability and self-efficacy have important predictive functions for the occurrence of behavior (Wurtele & Maddux, 1987). As explained by protection motivation theory, the role of each factor in behavior change is not unidirectional, thus climate change adaptation studies need to utilize empirically tested theories and provide as much understanding about the climate change adaptation practices of individuals as possible (Crossler & Belanger, 2014).

2.3 An integrated framework and hypothesis

Although there are many studies on the factors affecting climate change adaptation behavior, most of them use single theories such as the protective action decision model, TPB and

PMT for empirical explanations (van Valkengoed & Steg, 2019). It has been criticized that TPB is lacking in incorporating threat assessment – whether or not a threat exists and the extent of a threat into a framework for comprehending behavioral motivations (Kloeckner & Bloebaum, 2010). Moreover, the lack of combined effects of motivational factors in predicting adaptation and innovative applications of theories and methods is unable to fully explain the behavior. Researchers find that the lack of appropriate environmental cognitive behavioral and socio-psychological models and poor understanding of factors influencing environmental behavior, inhibit farmers from adopting pro-environmental behaviors in agricultural activities (Badsar et al., 2022). Studies focusing on the combination of TPB and PMT have been recognized as a possible way to explore the influences affecting human behavior incorporating both environmental cognition and socio-psychological factors. It has been used to explore farmer's sustainable environmental behavior (Badsar et al., 2022), non-point source pollution control and management behavior (Wang et al., 2019), user's secure behavior (Grimes & Marquardson, 2019), and intentions regarding COVID-19 booster vaccination (Zhou et al., 2022). This utilization of the integrated model further provides a better understanding of the behavior and intention of individuals than that provided by each construct when used individually (Wang et al., 2019). Based on the above analysis, it might not be sufficient for the unique context of adaptation behaviors of herdsmen in Inner Mongolia as a result of their high dependence on livestock income and high vulnerability to climate change risks. Their adaptation motivation is even more complicated, related to not only rational choice but also psychological factors.

Schwaller et al. (2020) noted that there are strong parallels between "perceived behavioral controls" in the TPB model and "coping perception" in the PMT model, with the latter describing a broader range. Furthermore, previous studies have shown that perceived behavioral control is closely related to the concept of self-efficacy, which has been investigated in terms of self and response efficacy in PMT (Badsar et al., 2022; Wang et al., 2019). Our research framework benefits from these observations. By combining PMT, TPB constructs, and climate experience, we aim to expand the range of psychological factors and evaluate whether this combined model is more effective in predicting the behaviors of herders. Thus, to comprehensively consider climate change adaptation behavior under the joint influence of individual rational decision-making and psychological perception.

This integrated framework includes comprehensive rational and perceptual factors by combining the strengths of these theories for greater accuracy. The decision process, according to social science treatments of rationality, includes the individual's subjective representation of the behavior decision-making (Simon, 1986), and attempts to determine empirically the cognition and attitude and their changes with time and experience. Researchers have shown that tracking farmer experiences with climate change are important in attitudes and behavior study (Arbuckle et al., 2013). Individuals' personal experiences with environmental changes are an essential motivator in increasing their awareness of the impacts of climate change and their willingness to participate in adaptation efforts (Marlon et al., 2021). Spence et al. (2011) suggested that individuals who have had climate-related experiences are more likely to adopt adaptive or mitigative behaviors. We, therefore, incorporate previous climate experience, which is defined as the individuals' objective experiences of changes in weather, climate and climate change-related impacts based on individual observations. We use three statements to measure the climate experience targeted to herders, "*I have experienced a decrease in water in rivers/wells due to climate change*", "*I have experienced a decline in* *the quality of my pasture due to climate change*", and "*I have experienced a reduction in the size of my livestock due to climate change*". Respondents are asked about their agreement with these statements that measure their climate experience. Thus, rational factors in this framework include the herder's attitude, subjective norm, and climate experience (see Fig. 3). Subjective norms can motivate behavior because they signal which behaviors are likely to be effective in a situation (Cialdini, 2007). Studies have found that an individual's attitude toward the result of behavior is more positive, the observed social norm is greater, then there will be a stronger intention to implement the behavior (Ajzen, 1991). Climate experience has been studied extensively in the literature and is hypothesized to shape people's perceptions of situations and influence judgments of outcomes (Demuth et al., 2016), while there exists a large amount of heterogeneity in the effects between studies (van Valkengoed & Steg, 2019).

Two major parts of perceptual processes in this framework are threat perception of climate change and coping perception, which are based on herders' rational judgment. Herders might expect how likely their livestock will adapt to an increase in temperature, more frequent droughts, or more irregular rain. These are specific climate events that can be observed in study areas. Zur and Klöckner (2014) found that the perceived severity of environmental threats has a positive effect on motivation for pro-environmental behaviors. And Carrete and Arroyo (2014) found a positive and significant relationship between per-

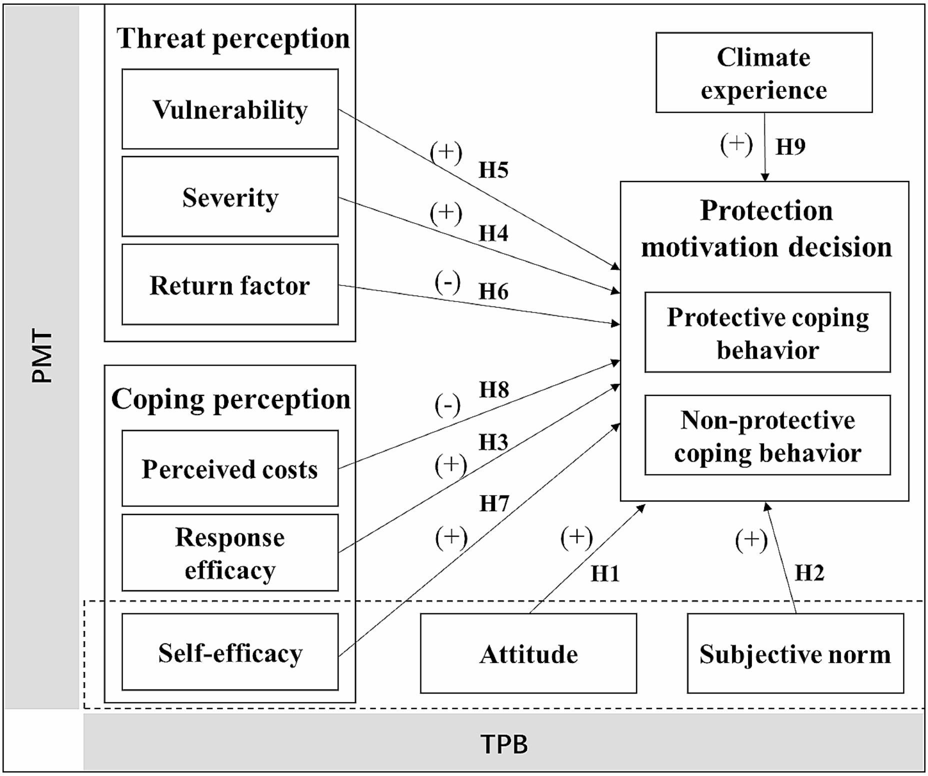

Fig. 3 Integrated framework of herdsmen's adaptation to climate change (Adopted and adjusted from Wang et al. (2019) and Badsar et al. (2022)

ceived vulnerability and the coping response. Perceived elements consisting of response efficacy, self-efficacy and response cost, have been specified and applied in certain studies, and they are the foundation for the conceptual framework of private proactive adaptation to climate change (Osberghaus et al., 2010). van Valkengoed and Steg (2019) found that perceiving higher levels of self-efficacy and stronger response efficacy were related to more adaptive behavior. Perceived response cost refers to the beliefs in how costly the coping responses will be (Grothmann & Patt, 2005; Milne et al., 2000). Zhao et al. (2016) found that response cost negatively affected behavior due to a lack of necessary materials and monetary resources. Following these rational and perceptual considerations, herders decide on protective coping or non-protective coping behavior. Drawing on relevant theories and literature, we formulated the following hypotheses to investigate herders' adaptation to climate change within the integrated framework, which includes constructs from the TPB and PMT theories, as well as climate experience:

H1 Attitude will have a positive effect on herders' adaptation behavior to climate change.

H2 Subjective norm will have a positive effect on herder's adaptation behavior to climate change.

H3 Response efficacy will have a positive effect on herder's adaptation behavior to climate change.

H4 Severity will have a positive effect on herder's adaptation behavior to climate change;

H5 Vulnerability will have a positive effect on herder's adaptation behavior to climate change;

H6 Return factor will have a negative effect on herder's adaptation to climate change;

H7 Self-efficacy (Perceived behavior control) will have a positive effect on herder's adaptation behavior to climate change;

H8 Perceived costs will have a negative effect on herder's adaptation behavior to climate change.

H9 Climate experience will have a positive effect on herder's adaptation behavior to climate change;

H10 Herder's adaptation to climate change depends on both rational and perceptual factors from the TPB, PMT and climate experience;

H11 The integrated model of a combination of PMT, TPB and climate experience has better predictability than the separate models.

3 Materials and methods

3.1 Study area

The study was conducted in highly climate-sensitive grassland areas dominated by animal husbandry and presented a range of climate hazards and grassland types. This research is notable for three main reasons. First, grassland is particularly vulnerable to climate change, which in turn affects livestock production. Second, climate change adaptation behavior is different from other pro-environmental behaviors. It highly depends on livestock production, which exposes to risks and uncertainties. Third, the herder's adaptation behavior to climate change is the result of considering various threats and planned expectations, we built the integrated model which is close enough to reality.

The data used in the empirical analysis of this paper was collected through a questionnaire[1] distributed to herders in the Inner Mongolia Autonomous Region and Gansu Province in 2020, both of which are climate-sensitive areas. The survey sites include West Ujimqin Banner, XilinHot, Sonid Left Banner, Otog Banner in Inner Mongolia, and Tianzhu Tibetan Autonomous County in Gansu Province (see Fig. 4). There are three reasons why we choose these six counties. First, all the above-mentioned areas are all animal husbandry counties. As a pillar of the local primary industry, animal husbandry is the main source of livelihood for herders. Second, study areas are represented by different grassland types and various climate events. It covers typical steppes, alpine meadow steppes and desert steppes. West Ujimqin Banner and XilinHot Banner are dominated by typical steppes, with snow disasters, wind disasters, and extreme heat being more prevalent; Sonid Left Banner and Otog Banner are dominated by desert steppes, with drought and wind disasters being more prevalent; and Tianzhu Tibetan Autonomous County is dominated by alpine meadow steppes, with floods and hail being more prevalent. Thirdly, the study area encompasses a range of economic development levels of the selected areas, including high, medium, and low levels, which are considered representative. This can comprehensively reflect the decisions of herders under various levels of economic development.

3.2 Simpling procedure

Our research involved collecting data from herder households in Inner Mongolia and the Gansu regions. We used a two-step, multi-stage quota sampling method for this purpose. In the first step, data was collected from meteorological stations to identify the occurrence of meteorological disasters, such as droughts and blizzards, in these regions over a year. The designed surveys cover a wide range of factors, including economic development level, geographical location, animal husbandry production scale, and regional population density. Based on this, six counties were identified for further investigation: West Ujimqin, XilinHot, Sonid Left Banner, Otog Banner in Inner Mongolia, and Tianzhu Tibetan Autonomous County in Gansu Province. The second step involved categorizing pastoral villages into three groups (near, medium, and far) based on their distance from the village committee to

[1] To ensure clarity and minimize ambiguity, we took two steps: First, we pre-tested the questionnaire with a small sample of participants to ensure comprehensibility. Second, we conducted a pilot study in the selected regions to ensure the questions' cultural relevance and appropriateness. The questionnaire is listed as a supplementary material.

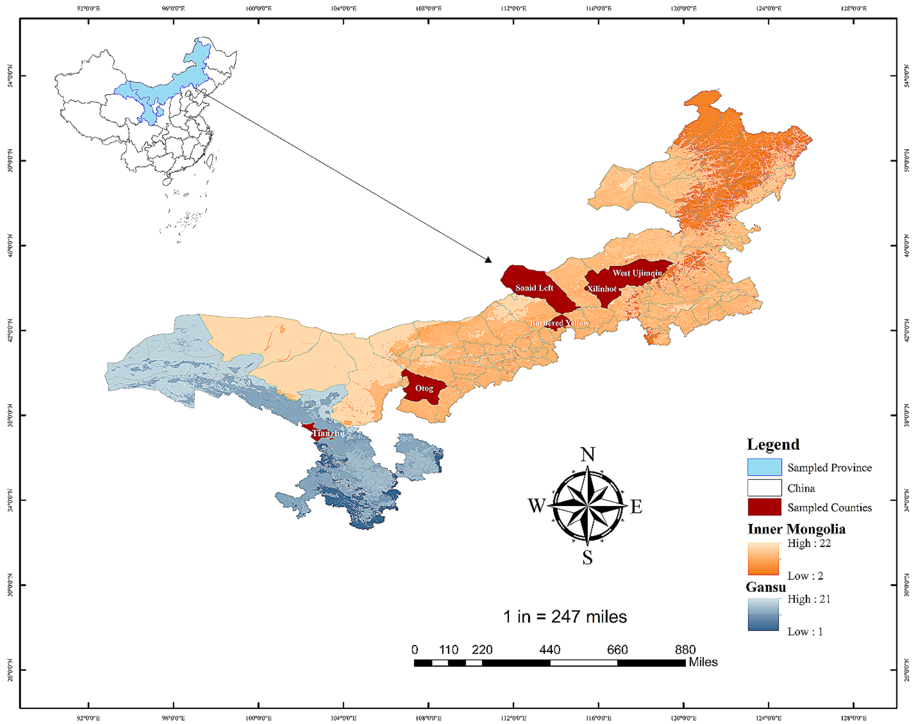

Fig. 4 Map of study area showing elevation (m). (Sources https://hub.arcgis.com)

the township government. From each town, three to five villages were chosen. Within each village, 10 to 15 herders were selected for interviews. Interviewees are selected within the quota in the designated area based on the investigator's subjective judgment. The survey included information on demographic characteristics, perceptions of climate change, adaptation behaviours, and responses to socio-psychological scale questions. The local ethics committee approved the survey, and informed consent was obtained from all participants. A total of 870 questionnaires were distributed, and 857 were returned after removing incomplete responses and those who failed to pay proper attention. Finally, 828 valid samples were obtained, and the effective rate of the sample was 95.17%. There are three types of grasslands: typical steppe, desert steppe, and meadow steppe. The effective samples are distributed relatively evenly across the three regions, with 32.85%, 33.09%, and 34.06% in each of them, respectively (see Supplementary Table S1). The survey includes basic demographic characteristics, questions related to climate change and adaptation behaviours, and socio-psychological scale questions.

3.3 Participants

Table 1 presents the demographic characteristics of the samples alongside the statistical average. To ensure accurate results for our research questions, our sample was specifically targeted towards individuals who are better equipped to answer questions pertaining to livestock production and comprised solely of pure pastoral residents. As indicated, the respon-

Table 1 Sample profile ($n=828$)

Variable	Definition	Frequency	Percentage	Sample average	Statistical average [a]
Gender	Male	621	75.00		55.06%
	Female	207	25.00		44.94%
Age	<30	63	7.61		32.04% [b]
	31–45	248	29.95		24.65%
	46–60	409	49.40		27.76%
	>60	108	13.04		15.55%
Nationality	The Han	226	27.30		83.76% [c]
	Mongolian	394	47.58		13.07%
	Tibetan	181	21.86		1.12%
	Others	27	3.26		2.05%
Education	Illiteracy	92	11.11		11.91%
	Primary school	274	33.09		25.71%
	Junior high school	281	33.94		31.12%
	High school	126	15.22		14.81%
	College degree and above	55	6.64		16.44%
Income (annual household)	<100,000 Yuan	172	20.77	234,475	84789.77
	100,000-200,000	215	25.97		
	200,000-300,000	177	21.38		
	300,000-400,000	103	12.44		
	>400,000 Yuan	161	19.44		

[a] Data sources used were the 2020 National Economic and Social Development Statistical Bulletin and the Main Data on the Seventh National Population Census. The average value was derived from three sets of city-level statistics, specifically those of Ordos, Xilingol, and Wuwei

dents were predominantly male (75%), with ethnic minorities such as Mongolian, Tibetan, and others making up 72.70% of the sample. The middle-aged and elderly herders (aged 31 to 60) constituted the majority of respondents, accounting for 79.35% of the sample. Approximately 68.12% of the herders in the total sample had an annual income of less than 300,000 Yuan, and the average annual family income was 270,800 Yuan[2]. Despite some differences between our sample and the statistical data, we believe that our sample provides a more accurate representation of the pastoral area due to it aligning with those of other scholars' sample statistics, further affirming the availability of our sample (Shi et al., 2021).

[2] The annual household income here refers to the total annual income of all family members, including all registered population even those who are migrant workers and other people who live in the household for a long time (more than 6 months in the current year).

3.4 Measures

3.4.1 Independent variables

In the current study, adaptation behaviors are divided into two stages, pre-disaster prevention and post-disaster adaptation, since they are both key periods to reducing losses from climate change. According to existing literature (Pan & Zhen, 2010; Jin et al., 2014; Zhang & Ai, 2018), in order to consider a comprehensive adaptation behavior, the specific measures including in our questionnaire are as following: increase the purchase of feed, reduce grazing days or increase captive days, adjust the livestock structure, reduce livestock storage, rent in grassland, rent out surplus grassland, rotational grazing, increase investment in well construction, shed construction, house feeding in winter, establish forage base, bank loans, private loans, purchase of livestock insurance, joint household operation, participation in pastoral cooperatives, feed new livestock breeds, forage variety improvement, and livestock improvement. And in order not to set scenarios in advance for the interviewed herdsmen, we assume that both pre-disaster adaptation and post-disaster adaptation include the above measures. The adaptation behavior is items described as "How often do you take preventive measures to prevent climate disasters from occurring?" and "How often do you take adaptive measures when a meteorological disaster occurs?" the answers are 5-point Likert type-scale from "1 = never" to "5 = always".

3.4.2 Integrated PMT and TPB constructs

We employed a set of instruments to measure the construct variables in our integrated TPB-PMT framework, namely attitude, subjective norms, perceived mediation process (severity, vulnerability, return factor, self-efficacy, response efficacy, and perceived cost) and adaptation behavior. In particular, the scales used for the measurement of these latent constructs were adapted from prior literature on climate change scenarios (Arbuckle et al., 2013, 2015; Azadi et al., 2019). In Table 2, the agreement levels of the statements measuring each latent variable (except for adaptation behavior) are presented using a 5-point Likert scale. The scale ranges from "1 = strongly disagree" to "5 = strongly agree", with intermediate points of "2 = relatively disagree", "3 = in general", and "4 = relatively agree".

3.5 The empirical model

Structural equation modeling (SEM) is an analytical tool for model identification, estimation and validation of various theory-based causal models using hypothesis testing methods in statistics. Allowing latent variables to consist of multiple measured variables, the factor structure and inter-factor relationships can be estimated simultaneously. The greatest advantage of this method over ordinary regression analysis is that it can deal with multiple dependent variables simultaneously, allows the explanatory and explained variables to contain measurement error, and incorporates this measurement error into the model with more accurate estimation results (Kline et al., 2011; Kline, 2010; Wang, 2010), and is, therefore, a more appropriate method for testing the model in this paper. The specific form of SEM is as follows:

Table 2 Measurements and descriptive statistics

Description of measurement items	Mean	S.D.
Adaptation behavior		
AB1: Frequency of preventive measures before meteorological disasters	4.10	0.873
AB2: Frequency of adaptive measures after meteorological disasters	4.14	0.834
Attitude		
ATT1: Climate change is not only a natural fluctuation but may also be caused by human activities	3.31	1.514
ATT2: I am quite sure that human activities are responsible for climate change.	3.27	1.431
ATT3: The main causes of climate change are human activities and natural causes.	3.53	1.373
Subjective norms		
SN1: Family members believe that timely attention to climate information is necessary for animal husbandry production and disaster prevention	4.43	0.698
SN2: Neighbors believe that timely attention to climate information is necessary for animal husbandry production and disaster prevention	4.41	0.703
SN3: Village heads believe that timely attention to climate information is necessary for animal husbandry production and disaster prevention	4.20	0.775
Climate experience		
CE1: I have experienced a decrease in water in rivers/wells due to climate change	4.33	0.882
CE2: I have experienced a decline in the quality of my pasture due to climate change	4.33	0.891
CE3: I have experienced a reduction in the size of my livestock due to climate change	4.11	1.054
Severity		
Sev1: Climate change will reduce the number of milk and beef cattle	4.22	0.964
Sev2: Climate change will lead to an increase in pests and diseases	4.20	0.949
Sev3: Climate change will lead to the depletion of biodiversity	4.09	1.016
Sev4: Climate change will lead to an increase in the incidence rate of diseases.	4.14	0.983
Sev5: The consequences of climate change will be harmful to the environment	4.40	0.772
Vulnerability		
Vul1: I'm vulnerable to the potential negative impact of climate change on animal husbandry	4.45	0.730
Vul2: I'm worried that climate change will harm my livestock production	4.46	0.734
Vul3: I'm worried that climate change will harm my family's health	4.17	0.847
Return factor		
RF1: Non-adaptation is easier than adaptation	3.51	1.290
RF2: Non-adaptation is more convenient than adaptation	3.49	1.295
RF3: Non-adaptation is less costly than adaptation	3.46	1.297
Response efficacy		
RE1: Adaptation can reduce the negative impact of climate change on the ecological environment	4.13	0.762
RE2: Adaptation can reduce the losses caused by climate change to the livestock industry	4.16	0.740
RE3: Adaptation can reduce the negative impacts of climate change on public health	4.05	0.812
Self-efficacy		
SE1: I believe that the little things I can do will make a difference to alleviate the negative effects of global warming.	3.53	1.083
SE2: I try to do something about climate change, and do not doubt if it will make any difference	3.13	1.147
SE3: I will not be helpless in mitigating the negative effects of climate change	3.18	1.172
Perceived cost		
PC1: Adaptation takes more time and energy than non-adaptation	4.30	0.665
PC2: Adaptation takes more money than non-adaptation	4.31	0.679

$$\eta = B\eta + \Gamma\xi + \zeta \tag{1}$$

$$Y = \Lambda_y \eta + \epsilon \tag{2}$$

$$X = \Lambda_x \xi + \delta \tag{3}$$

Equation (1) is the structural equation, where η is the endogenous latent variable, ξ is the exogenous latent variable, B is the coefficient matrix of the endogenous latent variable, Γ is the coefficient matrix of the exogenous latent variable, and ζ is the unexplained part of η. The latent variables can be reflected by the observed variables. Equations (2) and (3) are measurement equations that reflect the consistent relationship between the latent and observed variables. Where X is the vector of observed variables of the exogenous latent variable, Y is the vector of the observed variable of the endogenous latent variable, and Λ_y is the matrix of correlation coefficients between the exogenous latent variable and its observed variable, and Λ_x is the matrix of correlation coefficients between the endogenous latent variable and its observed variable, and ϵ, δ are the residual terms.

3.6 Reliability and validity test

To verify the internal consistency reliability and indicator validity of the model, we used exploratory factor analysis (EFA) to analyze the validity of the questionnaire. The results show good convergent validity and reliability (See Supplementary Table 2). In addition, we evaluated the discriminant validity of the measurement model via Confirmatory Factor Analysis (CFA). Higher composite reliability (CR) value indicates higher internal consistency of the constructs, and a higher average variance extracted (AVE) value indicates that the constructs have higher convergent validity (Fornell & Larcker, 1981). Our results of the validity test (see Supplementary Table 3) indicate a high internal consistency and provide evidence of good discriminative validity.

3.7 Model fitness analysis

Model fitness is an important basis for testing whether the theoretical model construction is scientific (Wu, 2010). We utilized AMOS software to perform structural equation modeling and obtain standardized fit indices in order to examine the relationships and effects among the variables in the TPB, PMT, and IM models and to evaluate their robustness (refer to Table 3). The integrated model demonstrated a smaller Root Mean Square Residual (RMR) value of 0.029 in structural equation modeling, indicating a better goodness-of-fit compared to the other two individual theories, which both had RMR values of 0.040. A smaller RMR value indicates a better fit between the model and the data. This confirms that the integrated model (RMR = 0.029, RMR ≤ 0.050) provides a better explanation for predicting and explaining herders climate change adaptation behavior than the other two individual theories (RMR = 0.040, RMR ≤ 0.050). Furthermore, the other indicators in Table 3 for the integrated model (IM) demonstrate that the chi-square ($\chi 2/df = 1.820$, $P < .001$) was within the normal range (less than 3), the CFI value (0.984) exceeded the cut-off value of 0.90, and the RMSEA value (0.031, 90% CI: 0.028, 0.035) was within the cut-off value of 0.05, indicating a strong overall fit. We are thus convinced that integrating these theories, along with

Table 3 Overall model suitability test

Fit indices	Cut-off value	TPB	PMT	IM	Evaluation
$\chi 2/df$	$1<\chi 2/df<3.00$	2.581	2.872	1.820	Fit
RMR	RMR ≤ 0.05	0.040	0.040	0.029	Fit
RMSEA	RMSEA ≤ 0.05	0.044	0.048	0.031	Fit
GFI	GFI ≥ 0.9	0.979	0.943	0.948	Fit
AGFI	AGFI ≥ 0.9	0.965	0.925	0.936	Fit
NFI	NFI ≥ 0.9	0.983	0.964	0.965	Fit
IFI	IFI ≥ 0.9	0.989	0.977	0.984	Fit
TLI	TLI ≥ 0.9	0.986	0.972	0.981	Fit
CFI	CFI ≥ 0.9	0.989	0.976	0.984	Fit

Note: A smaller value of RMR corresponds to a better fit. A perfect fit is indicated by an RMR of zero, while an RMR value below 0.1 is considered acceptable

climate experience, is more effective for understanding climate change adaptation behavior than relying solely on one theory. Therefore, we approve H11.

4 Results

Figure 5 displays the standardized coefficients of the path relationship diagrams for the TPB (5a), PMT (5b), and IM (5c) models. The integrated model highlights that the constructs of TPB and PMT as well as climate experience are significant predictors of adaptation behavior, and that there are correlations between these constructs. Our analysis found that severity had direct significant effects on subjective norms and climate experience. Subjective norms, in turn, had a direct impact on perceived cost and response efficacy. Additionally, vulnerability had significant effects on adaptation behavior, both directly and indirectly through several factors including attitude, subjective norm, climate experience, response efficacy, and perceived cost. Furthermore, attitude had a direct influence on climate experience and self-efficacy. These results reinforce the correlations between the constructs of TPB and PMT and further emphasize the importance and necessity of considering the integrated model when examining adaptation behavior.

The hypothesis testing was based on the integrated framework, which posits that adaptation to climate change is the outcome of a complex process in which multiple dimensions and attributes interact with one another. The relationships among the observed and latent variables of the integrated framework are presented in Table 4. The results show that the influence of attitude and subjective norms on adaptive behavior manifests itself as indirect positive effects through self-efficacy and climate experience, response efficacy, and perceived cost, respectively, supporting H1 and H2. Severity had no direct effect on adaptation behavior but had positive mediate paths through climate experience, subjective norm, and other coping perception factors, still supporting H4, and in line with the findings of Wang et al. (2019). The vulnerability had a negative direct influence on adaptation behavior, but the total effect was positive, supporting H5. Return factor had a negative impact on adaptation behavior, verifying H6. Response efficacy and self-efficacy had positive influences on adaptation behavior, while perceived cost had a negative indirect effect, supporting H3, H7, and H8. Climate experience had a direct positive effect on herders' adaptation behavior, supporting H9. Overall, these results support the hypothesis that herders' adaptation to climate change depends on both rational and perceptual factors from the TPB, PMT, and climate experience, supporting H10.

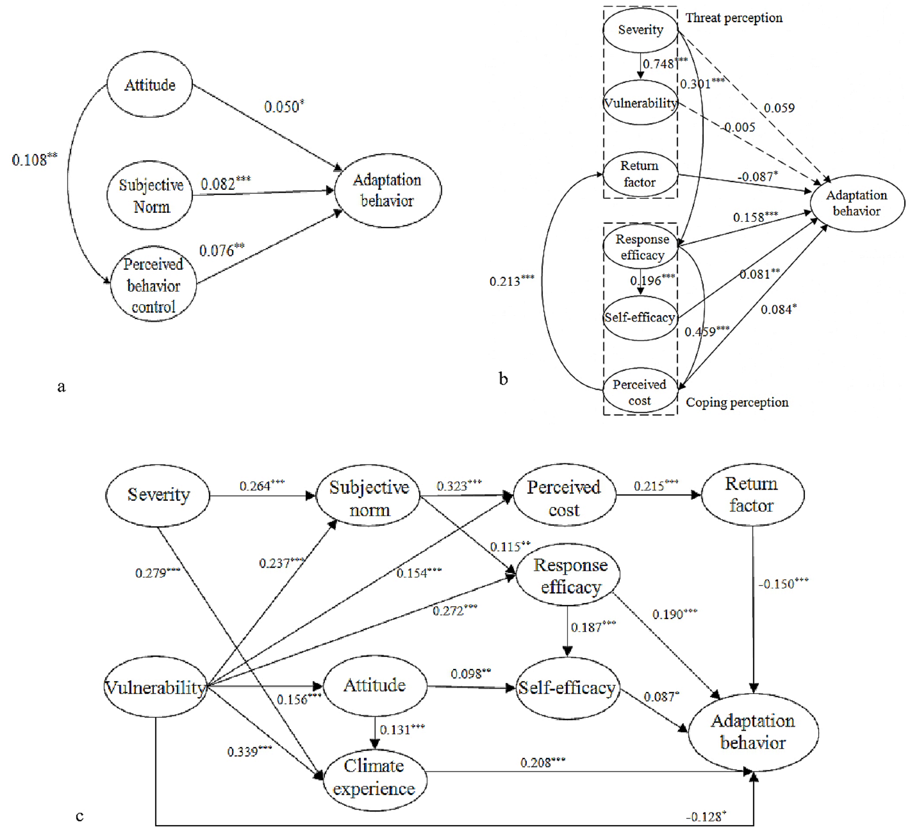

Fig. 5 Significance testing results of the structural model path coefficient. Notes: **a** - Standardized coefficients of the path relationship diagram for the TPB. **b** - Standardized coefficients of the path relationship diagrams for the PMT. **c** - Standardized coefficients of the path relationship diagrams for the integrated model (IM). Note: **a**, **b** and **c** were significant testing results of TPB, PMT and Integrated Model (IM), respectively. All the numbers represent the standardized coefficients of path relationships, * p < .05, ** p < .01, *** p < .001

Combining TPB and PMT constructs, we found a correlation between the model components. The influence path is embodied as the process of "threat perception (severity and vulnerability)-planned/experienced rational judgment (subjective norm, attitude and climate experience)-coping perception (response efficacy, self-efficacy and perceived cost)-adaptation behavior". The results confirm that the mechanism of adaptive behavior has experienced different considerations and judgments with multiple influence paths and temporal characteristics. It also indicates that integrating the two models with complementary features provides a better understanding of the herder's adaptation behavior to climate change in comparison to either TPB or PMT alone.

To visualize the causal effects among the latent variables in the structural equation model, Table 5 presents the direct, indirect and total effect values. Herder's climate experience (0.208) and response efficacy (0.196) have larger effects on climate change adaptation behavior, while self-efficacy (0.087) has a relatively small effect, followed by the return factor (-0.150) and vulnerability (-0.128), both of which have negative effects.

Table 4 Results of the integrated model

Paths			Non-standardized coefficient	S.E.	Critical ratio	Standardized coefficient	95% Confidence Interval	
SN	←	Vul	0.229***	0.054	4.251	0.237	0.131	0.343
SN	←	Sev	0.222***	0.049	4.552	0.264	0.168	0.360
RE	←	Vul	0.275***	0.041	6.775	0.272	0.192	0.352
ATT	←	Vul	0.318***	0.075	4.217	0.156	0.009	0.303
RE	←	SN	0.120**	0.042	2.874	0.115	0.033	0.197
PC	←	Vul	0.142***	0.036	3.983	0.154	0.083	0.225
PC	←	SN	0.309***	0.037	8.255	0.323	0.250	0.396
CE	←	Sev	0.274***	0.057	4.842	0.279	0.167	0.391
CE	←	Vul	0.385***	0.063	6.127	0.339	0.216	0.462
CE	←	ATT	0.073***	0.019	3.876	0.131	0.094	0.168
SE	←	RE	0.291***	0.057	5.077	0.187	0.075	0.299
SE	←	ATT	0.076**	0.028	2.655	0.098	0.043	0.153
RF	←	PC	0.426***	0.073	5.819	0.215	0.072	0.358
AB	←	RE	0.233***	0.053	4.403	0.190	0.086	0.294
AB	←	SE	0.069*	0.029	2.372	0.087	0.030	0.144
AB	←	Sev	0.054	0.068	0.797	0.050	-0.083	0.183
AB	←	Vul	-0.158*	0.081	-1.960	-0.128	-0.287	0.031
AB	←	CE	0.228***	0.058	3.959	0.208	0.094	0.322
AB	←	ATT	0.042	0.023	1.853	0.069	0.024	0.114
AB	←	SN	-0.046	0.056	-0.824	-0.036	-0.146	0.074
AB	←	RF	-0.101***	0.025	-4.034	-0.150	-0.199	-0.101
AB	←	PC	0.108	0.061	1.773	0.081	-0.039	0.201
Sev3	←	Sev	1			0.827	0.827	0.827
Sev2	←	Sev	0.923***	0.038	24.111	0.753	0.679	0.827
Sev4	←	Sev	0.959***	0.041	23.532	0.742	0.742	0.742
Sev5	←	Sev	0.965***	0.039	24.843	0.778	0.727	0.829
Sev6	←	Sev	0.785***	0.031	25.469	0.798	0.757	0.839
SE2	←	SE	1			0.930	0.930	0.930
SE1	←	SE	0.797***	0.026	30.18	0.786	0.731	0.841
SE3	←	SE	1.022***	0.025	41.094	0.930	0.930	0.930
Vul2	←	Vul	1			0.928	0.863	0.993
Vul3	←	Vul	0.886***	0.033	26.636	0.713	0.664	0.762
Vul1	←	Vul	1.018***	0.021	48.836	0.950	0.889	1.011
RE2	←	RE	1			0.932	0.932	0.932
RE1	←	RE	0.964***	0.028	34.985	0.873	0.793	0.953
RE3	←	RE	0.923***	0.031	29.821	0.784	0.784	0.784
ATT1	←	ATT	1			0.916	0.896	0.936
ATT2	←	ATT	0.916***	0.029	31.651	0.888	0.853	0.923
ATT3	←	ATT	0.738***	0.029	25.692	0.746	0.746	0.746
SN1	←	SN	0.996***	0.023	42.588	0.942	0.779	1.105
SN2	←	SN	1			0.939	0.859	1.019
SN3	←	SN	0.805***	0.033	24.271	0.686	0.610	0.762
CE3	←	CE	1			0.739	0.678	0.800
CE2	←	CE	1.015***	0.046	22.243	0.880	0.880	0.880
CE1	←	CE	0.850***	0.042	20.063	0.744	0.687	0.801
PC1	←	PC	1			0.950	0.893	1.007
PC2	←	PC	0.914***	0.041	22.27	0.850	0.850	0.850

Table 4 (continued)

Paths			Non-standardized coefficient	S.E.	Critical ratio	Standardized coefficient	95% Confidence Interval	
RF1	←	RF	1			0.970	0.880	1.060
RF2	←	RF	1.031***	0.01	98.601	0.997	0.915	1.079
RF3	←	RF	0.920***	0.018	49.89	0.888	0.843	0.933
AB1	←	AB	1			0.968	0.968	0.968
AB2	←	AB	0.815***	0.083	9.852	0.826	0.761	0.891

Note. * $p<.05$. ** $p<.01$. *** $p<.001$

Table 5 Direct, indirect and total effects in the integrated model

Paths			Direct effects	Indirect effects	Total effects
ATT	←	Vul	0.156	—	0.156
SN	←	Vul	0.237	—	0.237
SN	←	Sev	0.264	—	0.264
CE	←	ATT	0.131	—	0.131
CE	←	Sev	0.279	—	0.279
CE	←	Vul	0.339	0.021	0.360
SE	←	Sev	—	0.006	0.006
SE	←	SN	—	0.022	0.022
SE	←	ATT	0.098	—	0.098
SE	←	Vul	—	0.071	0.071
SE	←	RE	0.187	—	0.187
RE	←	SN	0.115	—	0.115
RE	←	Vul	0.272	0.027	0.299
RE	←	Sev	—	0.030	0.030
RF	←	SN	—	0.069	0.069
RF	←	Sev	—	0.018	0.018
RF	←	Vul	—	0.049	0.049
RF	←	PC	0.215	—	0.215
PC	←	SN	0.323	—	0.323
PC	←	Sev	—	0.085	0.085
PC	←	Vul	0.154	0.076	0.230
AB	←	SN	—	0.013	0.013
AB	←	ATT	—	0.036	0.036
AB	←	CE	0.208	—	0.208
AB	←	Vul	-0.128	0.151	0.024
AB	←	Sev	—	0.062	0.062
AB	←	SE	0.087	—	0.087
AB	←	RE	0.190	0.016	0.206
AB	←	PC	—	-0.032	-0.032
AB	←	RF	-0.150	—	-0.150

The total effect shows that climate experience (0.208) and response efficacy (0.206) have greater effects on adaptation. Followed by self-efficacy (0.087) and severity (0.062). Attitude (0.036), vulnerability (0.024) and subjective norm (0.013) have the smaller effects on adaptation. While the return factor (-0.150) and perceived cost (-0.032) show negative effects on adaptation. And we find that the perception process has greater effects on adaptation than rational factors, which demonstrates that adaptation behavior depends more on the herder's perceptual consideration than rational judgment. The results also prove that climate experience, return factor and self-efficacy only have direct effects on adaptation behavior. Subjective norm, attitude, severity and perceived cost have no direct effects on adaptation. while others have both direct and indirect effects on herder's adaptation to climate change. One interesting result is that vulnerability has a negative effect on adaptation directly, but the total effect on adaptation is positive. The indirect paths of vulnerability on adaptation include "vulnerability—climate experience—adaptation" and "vulnerability—subjective norm—subjective norm—return factor—adaptation", etc. This indicates that the sum of indirect effects offsets the negative effect of direct effects.

5 Discussion

The current research aims to contribute to a better understanding of the motivational mechanisms driving herders' responses to climate change. By examining the herders' adaptation behaviors, it is revealed that while TPB and PMT individually provide some insights, more is needed to fully capture the complex motivational frameworks that influence their decision-making processes. Our integrated model result shows that a combination of TPB and PMT with empirical data on herders' climate experiences predicts adaptation behaviors in pastoral regions of China. The complexity of adaptation actions, determined by various dimensions and attributes, is highlighted by the intercorrelation between the constructs of TPB and PMT, as well as herders' experiences with climate variability. Moreover, our study also reveals that the integrated model, which accounts for both rational choice and perceptual psychological cognition, highlights a mutual correlation between rational and perceptual factors. Perceptual knowledge is interpreted through rational judgement, resulting in a complex process of "threat perception-planned/experienced rational judgement-coping perception-adaptation behavior.

Our integrated framework demonstrates the indirect influence of threat perception, specifically perceived severity and vulnerability, on the adaptive behaviors of herders. This influence is mediated through attitude, subjective norm, and climate experience, which is similar to Wang et al.'s (2019) who found that non-point source pollution control among farmers. This finding indicates the pivotal role of threat perception in shaping the rational constructs, whether planned or experienced, that inform adaptive strategies. The attitudes and subjective norms of external entities indirectly shape herders' adaptive behaviors through various pathways tied to the constructs of perceived efficacy within coping perceptions. These insights underscore that such planned or experienced rational constructs significantly impact coping perceptions, which, in turn, directly inform the herders' adaptation behaviors.

Moreover, our integrated model accentuates that climate experience serves as a mediating factor in the nexus between perceived severity or vulnerability and climate change adaptation. This aligns with prior studies indicating that perceived severity or vulnerability mirrors the individual's firsthand experience with prevailing risks (Bockarjova & Steg, 2014), thereby reinforcing the interconnection between the constructs of the Theory of Planned Behavior (TPB) and the Protection Motivation Theory (PMT), alongside climate experience. Our study extends the existing body of research by integrating climate experience into the combined TPB and PMT framework, an approach yet to be extensively explored, particularly concerning the adaptive behaviors of herders in the pastoral regions of China. The findings also suggest that the influence of climate experience on adaptation behaviors related to climate change is more pronounced than other determinants. This research reveals that herders who have previously encountered climate change manifestations are inclined to implement adaptation strategies that are aligned with extant literature, illustrating that individuals with direct experiences of environmental events, such as flooding, are inclined to engage in behaviors aimed at climate change mitigation, such as adopting energy-efficient practices (Spence et al., 2011). Moreover, climate experience facilitates an enhanced comprehension of potential future risks and consequences associated with climate change, thereby fostering more direct and robust adaptation actions.

Contrastingly, this finding of integrated model diverges from prior studies, which suggested that subjective norms and attitudes predominantly influence environmental behaviors among farmers (Badsar et al., 2022; Wang et al., 2019). A plausible rationale for this discrepancy is the distinct nature of adaptation behaviors in herders, which are predominantly oriented towards addressing the uncertainties and threats encountered in livestock management. These threats pose imminent risks of tangible losses, thereby prioritizing risk mitigation and loss minimization in herders' decision-making processes. Furthermore, the study indicates that when herders perceive increased social pressure stemming from community norms, agreements, and ethical standards, their propensity to adopt climate change adaptation measures is heightened. This underscores the significance of integrating climate experience into the comprehensive model for analyzing herders' adaptation behaviors.

The results of our integrated model keep in line with previous studies. Herders' higher perception of vulnerability and severity is likely to enhance their motivation to adapt to climate change, which is consistent with the findings of previous studies (Janmaimool, 2017; Keshavarz & Karami, 2016; Badsar et al., 2022). However, the study also revealed an interesting result that the direct effect of vulnerability on adaptation is negative, indicating herders' fatalism. If the perceived vulnerability of climate change is greater, they may choose not to adapt due to a belief that nothing can be done to stop climate change or mitigate damages, as well as higher costs. Moreover, herders tend to consider the individual ability and the effects of adaptation and maladaptation, which is in line with previous research (Church et al., 2017; Wang et al., 2019; Zhao et al., 2016). The return factor plays a negative role in climate adaptation, which can be conceptualized as the benefits connected to maintaining current non-adaptive behavior, consistent with the results of Bockarjova and Steg (2014). Our study provide exclusive insights related to vulnerability effects on herders' adaptation behavior to climate change compare to other environmental friendly behavior. Thus, it emphasizes the significance of assist herders adaptation through increasing the ability of resilience and mitigate and reduce the vulnernability. The findings also show that response efficacy and self-efficacy (i.e., the perceived behavior control) of coping perception have significant effects on adaptation. Herders are more likely to take adaptation behavior when they feel they have the ability to adapt to climate change and the adaptation behavior can reduce the potential losses from the threat. This demonstrates that herders whose production and operation activities are more susceptible to climate change are more rational, consistent with Wang et al. (2019). They focus on the effects of response rather than the costs of response, which is in line with the description of "rational man" motivation in the expected value theory. Perceived costs have negative indirect effects on adaptation through the return factor, which is related to herders' negative perceptions toward barriers and the existence of costs such as financial, time, and effort to adapt to climate change. This further supports that it is vital to explain climate change adaptation decision through the integrated model of combining both rational and perceptual factors. In pastoral areas, the importance of costs is related to financial constraints, which are more related to farmers' short-term goals instead of long-term goals (Piemontese et al., 2024; Badsar et al., 2022). To promote enduring climate change adaptation in pastoral regions, it is essential to establish a sustainable financial framework, with a specific focus on mitigating the uncertainties arising from climate-related risks (Marcello Falcone & Sica, 2023).

6 Conclusions

Our current research has developed an integrated framework that combines the Theory of Planned Behavior (TPB), the Protection Motivation Theory (PMT), and climate-experience to explain the comprehension of the climate change adaptation behavior of herders. We have explored the causal relationships between the different constructs within TPB, PMT, and climate experience, emphasizing the significant influences of climate experience on climate change adaptation behavior. Our findings demonstrated a complex and temporal mechanism for adaptive behavior. This process involved the interaction of rational and perceptual factors, following the sequence: when people perceive a threat, they plan or experience a rational judgment, cope with the situation, and adapt their behavior. Specifically, the process begins with herders' perceptions of the severity and vulnerability to climate threats. Subsequently, they assess these perceived threats by drawing from their past experiences with climate while taking into account their attitudes, subjective norms, and external constraints. These factors collectively influence their motivation for engaging in adaptive behavior. As this motivation evolves, herders incorporate coping strategies into their decision-making process, examining their ability to adapt effectively, the efficiency of their adaptive strategies, and the associated costs in terms of time, finances, and effort. It is within this comprehensive context that herders participate in adaptive behavior.

Our study provides valuable insights for policymakers and researchers seeking to support and promote climate change adaptation in China's pastoral regions. We expand the discussion on the mechanisms by which psychological factors of climate change affect the adaptation behavior of Chinese herdsmen.

6.1 Implications for research and practice

The current study's findings have led to the formulation of the following recommendations. Firstly, it's crucial for decision-makers to acknowledge the importance of both rational and psychological factors when formulating strategies to adapt to climate change. This involves considering the climate-related experiences of herders, their individual attitudes, subjective norms, threat perceptions, and coping mechanisms. Secondly, there an urgent need to improve pastoral weather monitoring and information platforms. These platforms should provide precise and timely weather information to herders, regardless of their geographical location. Access to accurate weather data is essential for effective climate change mitigation and adaptation in the agricultural sector. Thirdly, decision-makers should allocate resources towards knowledge training and technical services that equip empower with the necessary skills and information for adapting to climate change. Such training should instill confidence in herders that the adaptation measures they implement are effective in addressing the challenges brought about by climate change. Lastly, a support mechanism should be established that provides resources for pastoral climate adaptation. This support should be designed with a comprehensive understanding of the primary concerns and needs of herders in adapting to climate change.

6.2 Study limitations

Despite the valuable contribution provided by this study regarding herders' adaptation behaviors and its effort to address limitations found in previous research, there are a few important considerations Firstly, the study is based on non-experimental, cross-sectional data. Although sensitivity tests have confirmed the reliability of the results, we should be cautious in asserting definitive causal relationships between the latent constructs evaluated and actual adaptation behavior. It would be beneficial for future research to replicate this study using longitudinal data from other pastoral regions. Secondly, the random sample only encompasses pastoral areas in Inner Mongolia and Gansu. This restricts the applicability of our findings beyond China's pastoral regions, especially in areas with diverse economic contexts and varying attitudes, perspectives, and understandings of climate change adaptation.

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Data availability The datasets used or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical approval Not applicable.

Consent to participate Not applicable.

Consent to publish Not applicable.

Informed consent Informed consent was obtained from all individual participants involved in the study.

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