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Climate Risk Perception and Household Adaptation Behaviour in Climate-Vulnerable Coastal Communities of Bangladesh

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Abstract: Household adaptation is crucial for building the resilience of coastal communities in Bangladesh, which face a high risk of impacts on their livelihoods and well-being due to climate change. This research aims to examine the behavioural determinants of household adaptation, and combines Protection Motivation Theory and the Theory of Planned Behaviour. It specifically focuses on the impact of climate risk perception, environmental knowledge, self-efficacy, and perceived response effectiveness on household adaptation behaviour by taking into account the mediating role of adaptation intention and the moderating role of community resilience. The data were taken from 230 households from six climate-vulnerable coastal districts (Khulna, Satkhira, Bagerhat, Barguna, Patuakhali, and Bhola) using a structured questionnaire with 5-point Likert scale items. Partial Least Squares Structural Equation Modelling (PLS-SEM) was used to analyse the proposed model. The results indicate that climate risk perception, environmental knowledge, self-efficacy, and perceived response effectiveness are significant factors that positively contribute to the formation of adaptation intention, which then determines household adaptation behaviour. The four antecedent variables' relationships with adaptation behaviour are also found to be significantly mediated by the variable adaptation intention. In addition, community resilience positively moderates between the relationship between adaptation intention and household adaptation behaviour, suggesting that community resilience can help to translate the intention to adapt into actual adaptation behaviour. The study is a contribution to the climate adaptation literature, as it proposes an integrated behavioural framework, and provides interesting policy implications for strengthening climate resilience through improved risk communication, environmental education, capacity building and community-based adaptation projects in climate-vulnerable coastal areas.

Keywords: Climate risk perception; Household adaptation behaviour; Adaptation intention; Community resilience; Coastal Bangladesh

1. Introduction

Climate change is among the most urgent challenges of our time and is disproportionately affecting developing countries, with environmental, social and economic costs. Bangladesh is one of the most climate-vulnerable countries in the world due to climate sensitive livelihoods, low-lying geography, high population density, and large coastal areas among these countries. The coastal communities are now facing recurrent cyclones, storm surges, floods, salinity intrusion, riverbank erosion, erratic rainfall and sea-level rise, all of which pose a threat to agricultural production, food security, public health and household livelihoods [1, 2, 3]. These environmental stressors have worsened socioeconomic vulnerabilities and livelihoods sustainability in rural areas and have pushed households to resort to different adaptation strategies to minimize climate-induced risks [4,

5]. But exposure to climatic hazards is not the only factor in adaptation. There is growing evidence that behavioural, cognitive, and institutional aspects are of equal importance for household climate risk perception, adaptation choice evaluation, and adaptation responses to environmental change [6, 7]. Thus, the knowledge of the behavioural factors that drive the household adaptation process has emerged as a key concern of researchers and policy-makers to enhance climate change adaptation in vulnerable geographic areas.

The research on climate adaptation in Bangladesh has significantly increased in the last decade, covering climate risk perception, indigenous knowledge, livelihood diversification, migration, disaster preparedness, gender, and food security. It has been demonstrated that households with higher climate risk perceptions are more likely to implement agricultural adaptation measures and livelihood diversification strategies [8, 9]. Local technologies and indigenous knowledge (IK) and community participation have also been recognised as assets to improve the adaptive capacity and resilience of coastal communities [10]. Likewise, studies have found that disaster experience, awareness of climate change and access to climate information motivate households to adopt preparedness actions and adaptive responses [2, 7]. Other studies have emphasized on gender responsive adaptation [11, 12], livelihood vulnerability [13], multidimensional community vulnerability [3] and behavioural adjustment in the context of food insecurity induced by climate change [14]. Studies have also found that climate change impacts migration decisions [15, 16], fertility preferences [17], and health-related practices [18], showing that climate change is not only about environmental deterioration but also about various facets of household well-being. All of these studies together suggest a need to consider environmental, behavioural, institutional and socioeconomic approaches together for successful climate adaptation.

However, there are a number of key research gaps. First, previous studies have focused on either determinants of observed adaptation behavior, agricultural adaptation strategies, livelihood resilience, vulnerability assessment or migration outcomes, and less attention has been paid to understanding the psychological processes underlying household adaptation decision making [5, 8, 9]. Specifically, adaptation intention, which is a direct determinant of the behaviour as suggested in the Theory of Planned Behaviour (TPB), has been less frequently integrated in empirical models of household climate adaptation in Bangladesh. Second, prior studies have explored the factors influencing the perceptions of climate risk, knowledge about the environment, adaptive capacity, disaster experience, and institutional barriers to adaptation separately, but rarely within a unified behavioural framework that considers Protection Motivation Theory and the Theory of Planned Behaviour [6, 7, 19]. Third, although community resilience is well acknowledged as vital in enhancing adaptive capacity [10, 20], there is limited empirical evidence on whether resilient communities can enhance household adaptation intentions to adaptation behaviours. These are necessary to understand, not only if households adapt, but also how and why some households are able to translate climate awareness into effective adaptive action and others are not.

In this context, the current study will focus on understanding behavioural determinants of household adaptation behaviour of climate-vulnerable coastal communities in Bangladesh based on the Protection Motivation Theory and the Theory of Planned Behaviour. In particular, the study examines how climate risk perception, environmental knowledge, self-efficacy, and perceived response effectiveness are associated with households' adaptation intention, and how adaptation intention affects household adaptation behaviour. Moreover, the mediating role of adaptation

intention in the relationship between cognitive determinants and adaptation behaviour, and the moderating role of community resilience in enhancing the intention–behaviour relationship are examined. The study of the psychological and contextual determinants together offers a holistic account of the process of household-level decision-making and implementation in the context of climate adaptation. This integrated perspective is especially prominent for coastal Bangladesh where repeated exposure to climate hazards, socioeconomic vulnerability, and institutional pressures interact to affect household decision-making, as Bhattacharjee et al., [3], Islam et al., [21], and Swarnokar et al., [5] have documented.

This study contributes to the climate adaptation literature in several important ways; both theoretical and empirical, and practical. Theoretically, it builds on the work of the Protection Motivation Theory, the Theory of Planned Behaviour, and combines the two in a single conceptual framework to account for cognitive and behavioral processes of household climate adaptation. This study differs from previous studies which mostly investigated the direct links between climate perceptions and adaptation outcomes because it explicitly considers adaptation intention as an important mechanism through which the relationship between climate perceptions and adaptation outcomes is mediated and community resilience as an important contextual moderator, providing a more comprehensive account of household adaptation behaviours. Empirically, the study makes an important contribution to the sparse behavioral research on climate adaptation in Bangladesh as it integrates climate risk perception, environmental knowledge, self-efficacy, perceived response effectiveness, adaptation intention, community resilience and household adaptation behaviour into one single analysis model. Lastly, the results will be useful policy implications for the government, non-governmental and development practitioners by identifying the behavioural and the community level factors which can enhance the climate resilience through targeted awareness programmes, environmental education, capacity building, community participation and institutional support. Finally, the study adds to an emerging body of evidence for people-centred and behaviourally informed climate adaptation solutions to support vulnerable coastal communities in Bangladesh.

2. Literature review

The perception of climate risk has been well established as a key factor influencing people's willingness to engage in adaptive measures in response to climate change. According to Protection Motivation Theory (PMT), intentions to adopt protective behaviours are more likely to be formed if climate-related threats are considered severe, likely to occur, and personally relevant. Climate risk perception has become an important determinant in adaptation decision-making in the context of Bangladesh, where coastal communities frequently face the threat of cyclones, storm surges, flood, salinity intrusion and river bank erosion. Ahmed et al. [8] reported that the perception of climate risk has a significant influence on the adoption of agricultural adaptation strategies, indicating that perception of climate risks is a driver towards adaptation. In a similar way, Rakib et al. [1] showed that there was strong correspondence between perceptions of local vulnerability and objective analysis of climate risks, further underscoring the role of subjective perceptions in adapting to climate risks. Freihardt [6] also found that attitudes to environmental risks do not necessarily match with the scientific reality, but the behaviours of households are more driven by the perceived risk. Shehab et al. [7] reaffirmed that past exposure to climatic hazards and risk perceptions significantly boost households' intention to adopt adaptation practices. Similarly, Rabbani et al. [15] demonstrated that

perception of climate risks can lead to either staying in a vulnerable area or seeking alternative livelihoods, and Vollan et al. [22] claimed that cognition bias and perceived risks play an important role in adaptation-related decision making. Overall, the studies suggest that those who perceive climate-related threats are more likely to form a stronger intention to engage in adaptive behavior, with the more severe the threat, the more likely they are to intend to act. Despite this, a large amount of the literature has concentrated on adaptation behaviour itself as opposed to the psychological process by which risk perception leads to behavioural intention. As adaptation intention as a motivational antecedent of behaviour is also a factor in PMT and the TPB, the link between intention and actual behaviour will provide a more complete understanding of household adaptation processes. Thus, the following hypothesis is suggested:

H1: Climate Risk Perception positively influences Adaptation Intention.

Another cognitive resource that can be of significance in building the household's ability to understand climate risks and adaptation opportunities is environmental knowledge. People who know more about the causes of climate change and the risks it poses are more likely to make a correct assessment about the risks and intentions to take measures to protect themselves. Presently, there is a consistent support from existing empirical evidence in Bangladesh that shows the role of environmental knowledge in adaptive response. Kibria et al. [10] showed that indigenous knowledge and locally developed technologies play a significant role in enhancing the adaptation and resilience of the coastal communities and emphasized the importance of the role of traditional knowledge and scientific knowledge in decision-making for adaptation. From an implementation perspective, Banu et al. [19] found that the knowledge of climate change mitigation is still low among the households in Bangladesh and is correlated with their implementation behaviour; hence, knowledge improvement can enhance the implementation behaviour. Islam et al. [21] also revealed that low educational attainment and low awareness level leads to low adaptive capacity of the households, which highlights the necessity of educational interventions to enhance the climate resistance of households. Mamun et al. [2] found that access to climate information and awareness of climate change were significant factors that influenced farmers' adaptation choices, and Swarnokar et al. [5] stated that although various locally suitable adaptation measures exist, lack of technical knowledge is one of the significant barriers to adaptation measure implementation. Additionally, Sojib et al. [12] emphasized the significant role of women's knowledge in household and community-level adaptation strategies, underscoring the importance of knowledge sharing in the context of inclusive climate resilience. Earlier research has found that there is a positive correlation between environmental knowledge and adaptation behaviour, but there has been a relative lack of research on the motivational chain that links the knowledge to adaptation intention prior to actual behavioural adaptation. TPB-based knowledge leads to improved behavioural beliefs and raises confidence in outcomes of adaptation to strengthen behavioural intentions. Therefore, it is expected that households with high levels of environmental knowledge will have high climate adaptation intentions. Therefore the following hypothesis is put forward:

H2: There is a positive impact of Environmental Knowledge on Adaptation Intention.

Central to Protection Motivation Theory, self-efficacy is the belief in an individual's ability to successfully execute adaptive behaviour and has been linked to behavioural change in the environmental arena. People with confidence in the ability, resources and skills to deal with the challenges of climate change are more likely to develop intentions to implement adaptive strategies.

The presence of confidence in adaptive capacity is found to have a significant impact on household decision making in Bangladesh when facing climate stress. Adaptive capacity, as measured by access to resources, was positively related to adaptive behaviour readiness, as observed by Ahmed et al. [8] that households with higher access to resources were more likely to adopt adaptation strategies. Swarnokar et al. [5] also found financial constraints, as well as lack of technical skills and institutional constraints to be major barriers for household actions to be taken as a result of awareness, suggesting that bolstering the confidence and capacities of households is a crucial requirement for effective adaptation. Islam et al. [21] also showed how low adaptive capacity by poor socioeconomically deprived households hinders adequate climate responses despite their high exposure to environmental hazards. Bhattacharjee et al. [3] also highlighted the importance of recognizing the interplay between multidimensional vulnerability (including limited socioeconomic resources and institutional capacity) and a diminished capacity to adapt and be resilient in coastal communities. Furthermore, Shehab et al. [7] identified that exposure to climatic hazards in the past increases the confidence of households to take adaptive action, thus fostering future adaptive action. While these studies offer indirect indication about the significance of self-efficacy, studies on self-efficacy's direct impact on adaptation intention are still limited within the Bangladeshi context. PMT suggests that one of the most powerful determinants of protective motivation is self-efficacy, and, therefore, households with more self-efficacy to adapt to climate change are likely to exhibit higher intentions for adaptation. It is therefore hypothesized that:

H3: Self-efficacy has a positive effect on Adaptation Intention.

Perceived response effectiveness is what people think can be achieved by taking certain adaptation measures to reduce the negative impacts of climate change. Protection Motivation Theory suggests that intentions to undertake behaviour change will be modest unless they think that the suggested adaptation actions will be effective in reducing the risks of the climate changes. However, there is enough empirical evidence in Bangladesh that the adaptation practice is more likely to be adopted at the household level when they see benefit from the interventions. Rahman et al. [9] showed that farmer awareness of the potential benefits of climate adaptation practices for enhancing agricultural productivity and food security positively influenced the adoption of these practices. Likewise, Mamun et al. [2] identified that crop diversification, farming practices and improved seed varieties were adopted by farmers as they perceived these as good adaptation options against climatic threats. However, Swarnokar et al. [5] indicated that the adoption of climate-resilient agriculture, saline-tolerant crops, elevated housing and rainwater harvesting by local communities increased following their discovery of benefits to reduce climate vulnerability, though financial and institutional barriers impede uptake. Kibria et al. [10] also demonstrated that indigenous technologies are still being implemented because they are considered to be suitable and effective solutions to local climate issues. Adaptive strategies were also significant drivers of reduced household food insecurity, further strengthening households confidence in the effectiveness of adaptation strategies, as identified by Tohan et al. [14]. In total, these studies suggest that, when households feel good about adaptation outcomes, this creates a positive incentive to invest in future adaptation. However, most of the previous studies have focused on actual adaptation practices, and little research has been conducted to understand the relationship between perceived response effectiveness and adaptation intention prior to actual adaptation. Households who think that adaptation strategies are effective

are more likely to have high intentions to take adaptation actions, guided by PMT. Based on this, it is proposed that the following hypothesis is accepted:

H4: Perceived Response Effectiveness has a positive impact on Adaptation Intention.

Adaptation intention is the most direct psychological antecedent of adaptation behaviour and plays a pivotal role in the TPB. Climate risk perception, environmental knowledge, self-efficacy and response effectiveness are likely to shape actual household adaptation, but these are anticipated to impact on the latter mainly through the formulation of behavioural intentions. There is empirical evidence from Bangladesh that shows that households that are more motivated to adapt to climate change are more likely to take practical measures. Ahmed et al., [8] found that agricultural adaptation practices were quite common among farmers who felt the need to adapt to climate risks. Rahman et al. [9] also revealed that when farmers had a positive perception about climate adaptation, it resulted in the adoption of climate adaptation measures, which in turn positively affected the food security of the households. Shehab et al. [7] reported that increased perceptions of climatic hazards drove household efforts towards disaster preparedness and livelihood adaptation. Among the households with a high willingness to adapt to climate change, swarnokar et al. [5] found that there was a widespread practice of climate-resilient farming, rainwater harvesting, raised homebuilding, and disaster preparedness. Additionally, Banu et al. [19] found that insufficient motivation, due to limited knowledge about climate change, correlated with lower implementation behaviours, and Sojib et al. [12] identified that positive attitudes towards women-led adaptation led to increased participation in household adaptation. Taken together, these results confirm the behavioural hypothesis that high adaptation intentions lead to greater likelihood of cognitive awareness being translated into adaptive practices. Relatively few studies, however, have explicitly modelled adaptation intention as a direct antecedent of household adaptation behaviour using an integrated behavioural framework. This is significant to fill this gap, especially in the understanding of the psychological mechanisms in climate adaptation processes among climate-vulnerable coastal households. Based on the Theory of Planned Behaviour and Protection Motivation Theory, the following hypothesis can be formulated based on the present study:

H5: Adaptation Intention positively influences Household Adaptation Behaviour.

Theories of behaviour have posited that perceptions and cognitive appraisals do not directly lead to adaptive behaviours but to behavioural intentions that, in turn, lead to behaviours. Both the Theory of Planned Behaviour (TPB) and Protection Motivation Theory (PMT) suggest that behavioural intention or protection motivation is the most immediate precursor to behaviour. Adaptation intention is the willingness to implement adaptation measures within the framework of climate change adaptation, which means reducing risks associated with climate change. While the impact of climate risk perception on adaptation behaviour in Bangladesh has been documented in past studies [1, 7, 8], the psychological pathway by which climate risks are translated into household adaptation is under-researched. Freihardt [6] also suggests that people react more to perceived risk to the environment than objectively measured risk, suggesting that intentions to behave are likely to be a key determinant in the pathway from perceived risks to adaptive responses. In the same way, Vollan et al. [22] show that adaptation choices are not only a function of objective environmental conditions, but also of cognitive processes and behavioural preferences. These findings suggest that the more climate-risk households feel, the stronger the intentions they have for climate adaptation, which in turn lead to climate adaptation measures. Yet, few studies have explored adaptation

intention as the behavioural chain between climate risk perception and household adaptation behaviour in Bangladesh. Thus, the current study develops an adaptation intention as a mediator in this relationship.

H6: Adaptation Intention plays a mediation role between Climate Risk Perception and Household Adaptation Behaviour.

Environmental knowledge has long been identified as a key motivational factor of adaptive behaviour as it improves knowledge of climate change, options for adaptation, and benefits of actions that can protect against it. However, knowledge does not automatically translate into behaviour if they are not motivated to use the knowledge in their practice. TPB proposes that knowledge contributes to behavioural beliefs that lead to enhanced behavioural intentions and a greater probability of behaviour change. There is empirical evidence to support this behavioural mechanism. Kibria et al. [10] show how indigenous knowledge and scientific knowledge helps coastal households to adapt and become more resilient in identifying adaptation approaches. Similarly, Banu et al. [19] highlights that implementation behaviour is linked to a lack of awareness of climate-related information, indicating that awareness alone is not enough without commitment to implementation behaviour. Mamun et al. [2] also note that issues related to climate information and awareness are important factors that influence the adaptation decision making of farmers, and Islam et al. [21] demonstrate that low levels of education and awareness limit adaptation, even at high levels of exposure. Swarnokar et al. [5] also find that households' lack of technical knowledge hinders the successful implementation of adaptation strategies despite their awareness of the risks associated with climate change. Collectively, these studies suggest that awareness of the environment generally leads to behaviour of adaptation, through an increase in the intention of the households to adopt to the environment. But little empirical studies have addressed the adaptation intention as the mediator mechanism especially among climate-vulnerable coastal communities of Bangladesh. Based on this, the following hypothesis is proposed for this study:

H7: Adaptation Intention is a mediator in Environmental Knowledge to Household Adaptation Behaviour.

Self-efficacy is a measure of households' confidence in their ability to successfully implement adaptation measures in the face of the challenges from climate change. Self-efficacy enhances the coping appraisal, which in turn increases the level of protection motivation and ultimately leads to protective behavior, argues PMT. A household's intentions to undertake adaptive actions are more likely to be formed before actually doing so if they feel they have the knowledge, skills, financial resources and capabilities to do so. This is indirectly supported by existing research. Adaptive capacity and access to resources are positively correlated with adaptation levels of households [8]. Bhattacharjee et al. [3] show that multidimensional vulnerabilities such as limited socioeconomic and institutional capacity constrain adaptive potential of coastal communities. Despite the recognition of climate risks, Swarnokar et al. [5] find that poor technical know-how, financial constraints, and institutional limitations are significant barriers to effective adaptation strategies among households. Similarly, Islam et al., [21] find that households with limited adaptive capacity find it more challenging to adapt well to climate change, and Shehab et al., [7] propose that households' confidence in adapting to climate change is boosted by their past experiences of climatic hazards. All of the above suggest that self-efficacy may not directly result in adaptation behaviour, but rather increases the motivation and intention of households to adapt, and in turn, to implement adaptation

behaviour. However, there is little empirical evidence that directly tests this mediating mechanism, so that the present study proposes the following hypothesis:

H8: Household Adaptation Behaviour is mediated by Adaptation Intention between Self-efficacy and Household Adaptation Behaviour.

Perceived response effectiveness is the belief of the households about the effectiveness of adaptation actions in reducing losses and enhancing resilience due to climate change. According to PMT, people will not take protective measures unless they think they will work. Thus, positive assessments of coping options should increase the predispositions to behave. There are ample empirical evidences in support of this behavioural pathway in Bangladesh. Rahman et al. [9] show that the adoption of adaptation measures is a response to farmers' perception that these measures enhance agricultural productivity and household food security. Mamun et al. [2] also observe that farmers shift to agricultural diversification, better crops, and changed farming systems when they become aware of their effectiveness in reducing the climatic risks. Kibria et al. [10] reveals that indigenous technology is still widely used because communities think it is effective adaptation technology that is appropriate to their environmental conditions. Swarnokar et al. [5] also note that households are more likely to adopt climate-resilient agriculture, rainwater harvesting, and raised floors following experimentation and testing, but financial and institutional constraints hinder adoption. The study conducted by Tohan et al. [14] further shows that adaptive strategies play an important role in alleviating food insecurity in the household, indicating positive assessment of the adaptation outcomes. These two studies, in combination, suggest that households that think adaptation actions are effective will be more likely to form robust intentions, leading to adaptation behavior. However, adaptation intention has not often been studied as the psychological mechanism which underlies this relationship. Hence the following hypothesis is suggested:

H9: Adaptation Intention plays a mediating role between Perceived Response Effectiveness and Household Adaptation Behaviour.

Community resilience – the social cohesion, institutional support, collective learning and shared resources of communities to anticipate, prepare for, respond to, and recover from climate-related shocks. Although behavioural intention is generally considered the most important determinant of adaptation behaviour, whether or not behaviour is observed is contingent upon the enablers in the community. The social networks, local governance, sharing, disaster preparedness, and institutional collaboration found in communities is strongly correlated with the opportunities afforded households to successfully implement intended adaptation measures. There is robust empirical evidence from Bangladesh which indicates the need for community resilience in the process of climate change adaptation. The results of Kibria et al. [10] indicate that indigenous knowledge, collective learning, and community participation significantly contribute to enhancing local resilience and adaptation outcomes. Similarly, Swarnokar et al. [5] find that institutional support, technical assistance, and active stakeholder engagement are more likely to build local adaptation effectiveness while weak governance and financial constraints are more likely to stifle local adaptation. Disaster preparedness is also influenced by social amplification of risk via community communication, collective experience and local interactions, showing that resilient communities can bolster preparedness and adaptive response of households, according to Rabbani and Cotton [20]. Rabbani et al. [15], also underline the need for place-based social relationships, community attachment and local support system to increase the adaptive capacity of the households that decide to stay in the

climate-vulnerable location. Moreover, Sojib et al. [12] show that community engagement and women's participation contribute significantly to strengthening collective adaptation and household resilience. While there is a consistent finding in previous studies on the positive effect of community resilience on adaptation outcomes, the study has not investigated whether community resilience can enhance overall association between the adaptation intentions of households and their adaptation behaviour. The present study builds on TPB and resilience theory and posits that having high adaptation intentions is likely to increase the probability of effective adaptation behaviour, if a household is part of a resilient community, which is defined as a community with supportive institutions, high social cohesion and collaborative adaptation practices. Based on this, the following hypothesis is put forward:

H10: The effects of Adaptation Intention on Household Adaptation Behaviour will be stronger in communities with higher values of Community Resilience.

Figure 1 shows the conceptual model of the study.

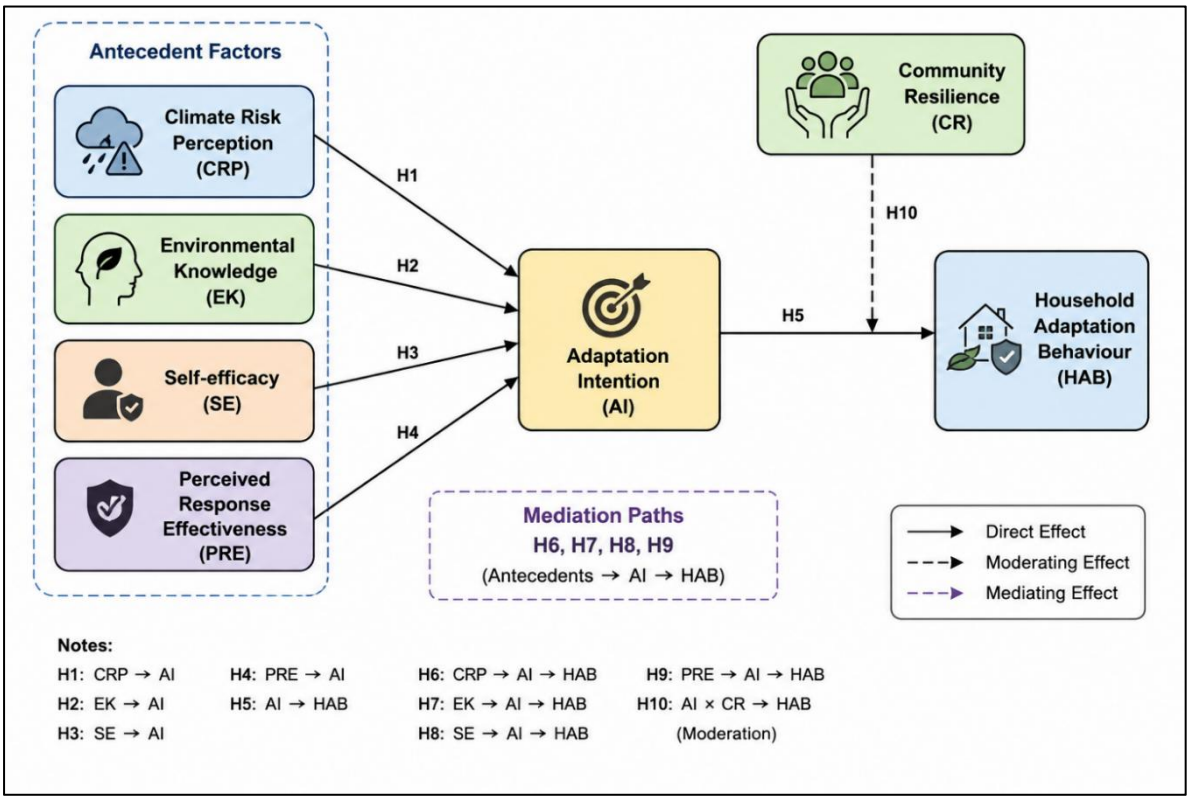


Figure 1. Conceptual framework

3. Methodology

The research design of this study was quantitative with cross-sectional approach and was aimed to explore the behavioural determinants of climate adaptation of the Household in climate-vulnerable coastal communities of Bangladesh. The empirical testing of the hypothesised relationships between climate risk perception, environmental knowledge, self-efficacy, perceived response effectiveness, adaptation intention, community resilience, and adaptation behaviour at the household level, integrated with a theoretical framework, warranted a quantitative approach. The study was based on Protection Motivation Theory (PMT) and the Theory of Planned Behaviour (TPB), two theories that have been widely used to explain intentions to act and protective behaviours towards environmental

risk. In view of the aim to investigate various direct, mediating and moderating relationships within the same study, a cross-sectional survey design was chosen to gather standardized data from the households who live in climate-vulnerable coastal areas. This design allowed the collection of similar responses from a relatively large number of participants within a short time frame and allowed multivariate statistical techniques to be used for the theory testing.

The study was carried out in six districts of the coastal areas of Bangladesh, which are among the most climate-vulnerable districts of the country: Khulna, Satkhira, Bagerhat, Barguna, Patuakhali, and Bhola. These districts are prone to cyclones, storm surges, tidal floods, salinity intrusion, river bank erosion, waterlogging and sea level rise, which makes them highly conducive to study the adaptation behaviour of households to climate change. The chosen districts also have a variety of ecological and economic characteristics, and a common vulnerability to climate change hazards. These areas are mainly devoted to agriculture, fishing, aquaculture and other natural resource-based livelihoods and local households are highly vulnerable to climatic variations and environmental degradation. Over the last decades, these districts have been hit by repeated extreme weather events, leading to significant losses of livelihoods, housing, crop productivity, fresh water and infrastructure. As a result, households in these regions have increasingly resorted to different adaptation options to respond to climate risks, offering a suitable empirical backdrop to study the behavioural processes that underpin household adaptation choices.

Household heads/ SH with sufficient knowledge on their livelihood activities and climate adaptation practices in the selected coastal districts were targeted. Household respondents were deemed the most meaningful unit of analysis as adaptation decisions tend to be made at the household level after a collective assessment of available resources, perceived risks and livelihood priorities. The respondents from the climate-affected communities were selected using a purposive sampling method. Purposive sampling was deemed appropriate as the study aimed for participants that had first-hand experience with the climate related hazards and had the ability to give informed reflections on climate perceptions, intentions to adapt, and household adaptation practices. Climate hazard areas known to affect communities were screened with the help of secondary sources, local government officials, and community leaders for communities that had experienced recurrent climate hazards. In each of these communities, households were approached and invited to participate voluntarily in the survey, according to the selection criteria [23]. Even so, the possibility of achieving statistical generalisation has been limited by the use of probability sampling in climate adaptation studies, as the focus has been on collecting rich information from those most impacted by climate change and with relevant adaptation experiences.

Data were collected using a structured questionnaire using face to face interview technique. Personal interviews were preferred because literacy levels are highly variable between coastal communities and interviewer assistance enabled respondents to accurately answer survey questions, while reducing missing data. Before gathering the data, respondents were told the goals of the study, and that their participation was totally voluntary. The use of confidentiality and anonymity were assured and informed consent was sought prior to the start of each interview. Ethical considerations about voluntary participation, confidentiality, privacy and the right to withdraw from the survey at any time were strictly adhered to during the data collection process. Questionnaire were distributed in total of 250 in the selected districts. The questionnaires were checked for completeness, consistency and missing answers and 230 questionnaires were found to be usable, giving a response rate of 92%.

To ensure the quality and reliability of the data set, responses with a high proportion of missing answers, inconsistent responses or signs of response bias were excluded.

The questionnaire was designed around existing validated measurement scales from the literature of climate adaptation, environmental behaviour and behavioural sciences. The survey instrument had two parts. The first section gathered the demographic and socio-economic data of the respondents such as gender, age, education, occupation, household size, monthly household income and previous experience of climate disaster. The second section assessed latent constructs contained in the proposed research model namely climate risk perception, environmental knowledge, self-efficacy, perceived response effectiveness, adaptation intention, community resilience, and household adaptation behaviour. A few wording adjustments were made to apply the original measurement items to the socioeconomic and cultural context of coastal Bangladesh but keeping the conceptual meaning of the items unchanged. All the items in the questionnaire were translated to Bangla for respondents' better understanding, and the translated questionnaire was meticulously reviewed to understand the meaning with linguistic clarity and conceptual similarity with English questionnaire.

The questionnaire was content validated and field-tested before the main survey to ensure its content validity and good quality. First, the draft questionnaire was subjected to an academic review of experts in research fields of climate change adaptation, environmental management and survey methods. Some questionnaire items were strengthened and clarified based on their comments. Later, a small set of respondents from climate-vulnerable communities not in the final survey sample were interviewed in a pretest. The pre-testing exercise allowed the researchers to recognize ambiguous wording, culturally inappropriate words, and possible problems that the respondents faced when responding to the items in the interview. Using the respondents' answers and the interviewers' observations, a few minor adaptations were made to the items to simplify the wording, streamline the sequence of questions, and minimize the effort of the respondents without altering the theoretical development of the measurement scales.

A pilot test of the survey instrument was carried out after the pretest in order to determine the instrument's reliability and feasibility prior to its use in full-scale data collection. The pilot survey validated the items in the questionnaire and the anticipated survey time. Preliminary reliability analysis showed that the internal consistency of the measurement items was satisfactory, implying consistency in the measurement of the constructs. The pilot study also served to test the effectiveness of the interview protocol, train enumerators and to discover any logistical problems with household data collection. The information elicited from the pilot survey helped to fine-tune the questionnaire as well as increase the reliability and validity of the research instrument.

Each of the constructs was measured on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The five-point scale was chosen for its simplicity, ease of understanding by the respondents and common use in behavioural, environmental and climatic adaptation studies. The scale also minimizes respondent fatigue and has enough variability to show differences in attitudes, perceptions, intentions and behavioural responses. The higher the scores the greater the agreement with each of the statements, thus the higher the scores, the higher the level of the underlying construct. To maintain uniformity on all latent variables and for subsequent statistical analysis, a standardized Likert scale was used.

The data collected were analysed by Partial Least Squares Structural Equation Modelling (PLS-SEM) using Smart PLS software. The selection of PLS-SEM was motivated by the fact that it is especially appropriate for predictive research, theory development, and simultaneous estimation of complex structural models with multiple latent variables, mediating effect, and moderating relationships. PLS-SEM is appropriate for the present study because it has less restrictive assumptions in terms of data normality and works well with relatively moderate sample sizes when compared to covariance based SEM. In addition, PLS-SEM can be used with reflective measurement models and allows for full evaluation of both the measurement and structural models in a single analytical framework.

4. Results

Table 1 shows the demographic characteristics of the 230 household respondents involved in the study. The majority of the sample was male (67.0%) and female (33.0%). As far as age is concerned, the majority of the respondents (30.9%) were in the age group of 31 to 40 years, followed by 41 to 50 years (28.3%), 18 to 30 years (18.3%), and above 50 years (22.6%) indicating that the majority of the participants were in the economically active age group. In terms of education level, secondary education was the most prevalent (36.5%), followed by primary education (24.3%), higher secondary education (17.0%), no formal education (12.2%) and bachelor's degree or above (10.0%). One-third of the respondents (33.0%) were mainly engaged in agriculture, while fishing, small business, day labour and service / other occupations come next in the livelihood structure of the coastal people of Bangladesh. Household income data indicate that 35.2% of respondents earned between BDT 15,001 and 25,000 per month, while 25.2% earned BDT 25,001–35,000, 22.6% earned less than BDT 15,000, and 17.0% earned more than BDT 35,000. Almost half of the households (47.0%) were composed of 5-6 members, while 27.8% of the households had 1-4 members and 25.2% had over 6 members. The majority of the respondents (84.3%) reported having experienced disaster before, showing a high exposure to climate disaster of the households sampled. Finally, the respondents were equally distributed across the six selected districts located on the coastal areas to ensure balanced geographical representation of the climate-vulnerable communities incorporated in the study including Khulna, Satkhira, Bagerhat, Barguna, Patuakhali and Bhola districts.

Table 1. Demographic Profile of Respondents (n = 230)

Variable	Category	Frequency	Percentage (%)
Gender	Male	154	67.0
	Female	76	33.0
Age	18–30 years	42	18.3
	31–40 years	71	30.9
	41–50 years	65	28.3
	Above 50 years	52	22.6
Education	No formal education	28	12.2
	Primary	56	24.3
	Secondary	84	36.5
	Higher Secondary	39	17.0
	Bachelor or above	23	10.0
Occupation	Agriculture	76	33.0
	Fishing	51	22.2

Variable	Category	Frequency	Percentage (%)
	Small business	39	17.0
	Day labour	35	15.2
	Service/Others	29	12.6
Monthly Household Income (BDT)	<15,000	52	22.6
	15,001–25,000	81	35.2
	25,001–35,000	58	25.2
	>35,000	39	17.0
Household Size	1–4 members	64	27.8
	5–6 members	108	47.0
	More than 6 members	58	25.2
Previous Climate Disaster Experience	Yes	194	84.3
	No	36	15.7
District	Khulna	39	17.0
	Satkhira	38	16.5
	Bagerhat	37	16.1
	Barguna	38	16.5
	Patuakhali	39	17.0
	Bhola	39	17.0

Descriptive statistics of the seven latent constructs in the study are presented in Table 2. In general, the average scores reflect generally high degrees of climate-related awareness, behavioural intentions and adaptation practices. Among the variables, climate Risk Perception had the highest mean value (M = 4.12, SD = 0.63), indicating that the households had high perception of risk of climate change in coastal areas of Bangladesh. Adaptation Intention also had a high mean score (M = 4.08, SD = 0.61) which represents a strong intention to implement adaptations to mitigate climate vulnerability. The mean scores for Perceived Response Effectiveness (M = 3.95, SD = 0.66), Environmental Knowledge (M = 3.89, SD = 0.71), and Household Adaptation Behaviour (M = 3.86, SD = 0.64) were also relatively high, indicating positive perceptions of the effectiveness of adaptation measures, moderate environmental knowledge, and moderate household-level adaptation behaviours. The mean scores for self-efficacy (M = 3.78, SD = 0.68) and Community Resilience (M = 3.72, SD = 0.69) were also positive, suggesting that a preponderance of respondents had confidence in their coping capacity and felt moderately to highly resilient in their communities. The standard deviations for each of the constructs ranged from 0.61 to 0.71 reflecting acceptable variation in responses with no excessive dispersion. In addition, the minimum and maximum values observed show that the respondents used a wide range of the five-point Likert scale, which allowed for a good variation in the values used for subsequent structural equation modelling analysis.

Table 2. Descriptive Statistics of Study Constructs

Construct	No. of Items	Mean	Standard Deviation	Minimum	Maximum
Climate Risk Perception (CRP)	5	4.12	0.63	2.20	5.00
Environmental Knowledge (EK)	5	3.89	0.71	1.80	5.00
Self-efficacy (SE)	5	3.78	0.68	1.60	5.00
Perceived Response Effectiveness (PRE)	5	3.95	0.66	2.00	5.00
Adaptation Intention (AI)	5	4.08	0.61	2.20	5.00

Construct	No. of Items	Mean	Standard Deviation	Minimum	Maximum
Community Resilience (CR)	5	3.72	0.69	1.80	5.00
Household Adaptation Behaviour (HAB)	5	3.86	0.64	2.00	5.00

Factor loadings of all items used to measure the seven latent constructs are presented in Table 3. The results show that all indicator loadings exceeded the recommended threshold value of 0.70 as proposed by Hair et al. [23], which indicates that the indicators had good reliability and each indicator is representative of its construct. Namely, the factor loadings for the variables of Climate Risk Perception, Environmental Knowledge, Self-efficacy, Perceived Response Effectiveness, Adaptation Intention, Community Resilience and Household Adaptation Behaviour were 0.811 to 0.872, 0.813 to 0.884, 0.803 to 0.871, 0.825 to 0.876, 0.846 to 0.883, 0.817 to 0.862 and 0.831 to 0.879, respectively. Items EK3 (0.884), AI2 (0.883) and HAB2 (0.879) showed the highest loadings, suggesting that these items were highly correlated with the constructs they measured. All outer loadings were well above the minimum acceptable value of 0.70, and thus there was no need to delete measurement items during the measurement model assessment. Indicator loadings greater than 0.70 suggest that over 50% of the variance in an item is accounted for by the latent construct, which suggests that the indicators are highly reliable and that the reflective measurement model employed in this study is adequate [23].

Table 3. Factor Loadings of Measurement Items

Construct	Item	Factor Loading
Climate Risk Perception (CRP)	CRP1	0.834
	CRP2	0.872
	CRP3	0.845
	CRP4	0.811
	CRP5	0.857
Environmental Knowledge (EK)	EK1	0.821
	EK2	0.846
	EK3	0.884
	EK4	0.839
	EK5	0.813
Self-efficacy (SE)	SE1	0.803
	SE2	0.847
	SE3	0.871
	SE4	0.828
	SE5	0.852
Perceived Response Effectiveness (PRE)	PRE1	0.832
	PRE2	0.861
	PRE3	0.876
	PRE4	0.843
	PRE5	0.825
Adaptation Intention (AI)	AI1	0.864
	AI2	0.883
	AI3	0.871
	AI4	0.846
	AI5	0.857

Construct	Item	Factor Loading
Community Resilience (CR)	CR1	0.817
	CR2	0.851
	CR3	0.834
	CR4	0.862
	CR5	0.826
Household Adaptation Behaviour (HAB)	HAB1	0.842
	HAB2	0.879
	HAB3	0.854
	HAB4	0.831
	HAB5	0.868

The reliability and convergent validity test for the study constructs is given in Table 4. The results reveal good internal consistency reliability for all constructs with Cronbach's alpha ranging from 0.881 to 0.907, which is above the threshold value of 0.70 recommended by Hair et al., [23]. In a similar way, rho_A ranges between 0.884 and 0.909, which further indicates the consistency of the measurement scales. In PLS-SEM, Composite Reliability (CR) is considered a more stringent indicator of internal consistency ranging between 0.913 and 0.931, well above the minimum threshold of 0.70 and below the maximum threshold of 0.95, thus showing internal consistency without redundant items in the measurement models [23]. Moreover, the Average Variance Extracted (AVE) values vary from 0.678 to 0.731 and are all higher than the threshold value of 0.50, indicating that each construct accounts for more than 50% of the variance of its indicators and thus satisfying convergent validity. The Adaptation Intention construct has the highest reliability and convergent validity (Cronbach's Alpha = 0.907, CR = 0.931, AVE = 0.731), and the Environmental Knowledge construct has the lowest but still acceptable values (Cronbach's Alpha = 0.881, CR = 0.913, AVE = 0.678). The results indicate that, in general, the measurement model has high internal consistency and convergent validity, meeting the criteria suggested by Hair et al. [23], and making the constructs suitable for the subsequent structural model analysis.

Table 4. Reliability and convergent validity assessment

Construct	Cronbach's Alpha	rho_A	Composite Reliability (CR)	Average Variance Extracted (AVE)
Climate Risk Perception (CRP)	0.892	0.895	0.920	0.697
Environmental Knowledge (EK)	0.881	0.884	0.913	0.678
Self-efficacy (SE)	0.886	0.889	0.916	0.685
Perceived Response Effectiveness (PRE)	0.894	0.897	0.922	0.703
Adaptation Intention (AI)	0.907	0.909	0.931	0.731
Community Resilience (CR)	0.884	0.888	0.915	0.682
Household Adaptation Behaviour (HAB)	0.901	0.904	0.927	0.719

The Fornell–Larcker criterion for testing the discriminant validity of the latent constructs is shown in Table 5. Hair et al. [23] suggests that discriminant validity is achieved if the square root of AVE for each construct is higher than the correlation between each construct. The diagonal elements which are the square root of AVE are between 0.823 and 0.855 and are all greater than the various off

diagonal correlations in the same row/column (as shown in Table 5). In particular, the diagonal values are higher than the inter-construct correlations for the variables Climate Risk Perception (0.835), Environmental Knowledge (0.823), Self-efficacy (0.828), Perceived Response Effectiveness (0.838), Adaptation Intention (0.855), Community Resilience (0.826), and Household Adaptation Behaviour (0.848). The highest correlation was found between Adaptation Intention and Household Adaptation Behaviour (r = 0.708), which is still less than the square root of the AVE for both constructs. These results substantiate that each of these constructs measures a unique concept with good discriminant validity using the Fornell–Larcker criterion as suggested by Hair et al. [23].

Table 5. Fornell–Larcker discriminant validity matrix

Construct	CRP	EK	SE	PRE	AI	CR	HAB
CRP	**0.835**						
EK	0.523	**0.823**					
SE	0.481	0.557	**0.828**				
PRE	0.564	0.592	0.546	**0.838**			
AI	0.641	0.628	0.603	0.669	**0.855**		
CR	0.412	0.471	0.503	0.486	0.554	**0.826**	
HAB	0.532	0.501	0.519	0.563	0.708	0.615	**0.848**

Note: Diagonal values (bold) represent the square root of AVE.

Table 6 shows the Heterotrait–Monotrait Ratio (HTMT), which is a more stringent measure of discriminant validity in the context of Partial Least Squares Structural Equation Modelling. Hair et al. [23] suggest that HTMT values be kept below the conservative level of 0.85 (or 0.90, depending on the situation) to assure that constructs are empirically distinct. The results show that all HTMT values are below the recommended value, ranging between 0.486 and 0.812. The highest value of HTMT is found between Adaptation Intention and Household Adaptation Behaviour (0.812) and the lowest is found between Climate Risk Perception and Community Resilience (0.486). All the HTMT ratios are below the critical value, which indicates good evidence of conceptual and statistical differences between the latent constructs. Hence, the results meet the HTMT criterion recommended by Hair et al. [23] which further highlights the discriminant validity of the measurement model and make it applicable for structural model estimation.

Table 6. HTMT discriminant validity results

Construct	CRP	EK	SE	PRE	AI	CR	HAB
CRP	—						
EK	0.604	—					
SE	0.548	0.639	—				
PRE	0.645	0.681	0.618	—			
AI	0.728	0.706	0.684	0.742	—		
CR	0.486	0.538	0.572	0.551	0.624	—	
HAB	0.611	0.582	0.597	0.652	0.812	0.703	—

Table 7 shows the assessment of multicollinearity (Variance Inflation Factor (VIF)) of all predictor constructs of the structural model. In PLS-SEM, the assessment of collinearity is important, as the presence of high multicollinearity among the predictor variables may lead to overestimating standard errors, and the stability and interpretation of the path coefficients may be misled. Hair et al.

[23] suggests that VIF values below 3.0 is acceptable and values below 5.0 (a more conservative measure) suggest multicollinearity is not an issue. The VIF values for the predictors of Adaptation Intention range from 2.039 (Self-efficacy) to 2.351 (Perceived Response Effectiveness) whereas the predictors of Household Adaptation Behaviour show a range of 1.562 (interaction term Adaptation Intention × Community Resilience) to 1.983 (Adaptation Intention). The VIF value for Community Resilience is 1.774 and is also well within the acceptable range. As noted, all VIF values are significantly below the recommended value, which indicates that multicollinearity was not present among the predictor constructs. Thus it is seen that each independent variable brings its own unique explanation to the structural model and no collinearity exists to threaten the validity of the structural model, with estimated path coefficients that are robust and reliable.

Table 7. Variance inflation factor (VIF) results

Predictor	Adaptation Intention	Household Adaptation Behaviour
Climate Risk Perception	2.116	—
Environmental Knowledge	2.284	—
Self-efficacy	2.039	—
Perceived Response Effectiveness	2.351	—
Adaptation Intention	—	1.983
Community Resilience	—	1.774
AI × CR (Interaction Term)	—	1.562

As results of the structural model analysis for direct relationships (H1–H5) are shown in Table 8. Results show that all the pathways assumed in the hypothesis are positive and significant, so it can be said that the conceptual framework that has been proposed can be accepted. Specifically, Climate Risk Perception positively impacts Adaptation Intention ($\beta = 0.281$, $t = 4.607$, $p < 0.001$), thus supporting H1 and indicating that households who perceive less climate risk are less likely to form an intention to adopt adaptation measures. Environmental Knowledge also has a positive impact on Adaptation Intention ($\beta = 0.196$, $t = 3.379$, $p = 0.001$); thus, H2 is supported, and a greater understanding of the environment and adaptation options leads to greater household willingness to adapt. Similarly, Self-efficacy has a large positive influence on Adaptation Intention ($\beta = 0.215$ $t = 3.839$ $p < 0.001$) supporting H3 which indicates that those households who express more confidence in their ability to adapt to climate-related challenges tend to show stronger adaptation intentions. Perceived Response Effectiveness has the highest impact ($\beta = 0.327$, $t = 5.542$, $p < 0.001$) in Adaptation Intention, supporting H4 and indicating that households are more motivated to adapt when they perceive that adaptation responses are effective in reducing climate risks. Lastly, there is a good positive effect of Adaptation Intention on Household Adaptation Behaviour ($\beta = 0.654$, $t = 13.347$, $p < 0.001$) and thus H5 is also well supported. This relationship shows the highest t-value and the largest standardized path coefficient of all direct relationships, implying that intention to adapt is the most important direct relationship with household adaptation behaviour. As a whole, the results of the structural model indicate that all the five direct hypotheses are supported, suggesting the importance of cognitive and behavioural factors in shaping the household adaptation decisions in climate-vulnerable coastal communities.

Table 8. Structural model path coefficients (H1–H5)

Hypothesis	Path	β	Standard Error	t-value	p-value	Decision
H1	Climate Risk Perception → Adaptation Intention	0.281	0.061	4.607	<0.001	Supported
H2	Environmental Knowledge → Adaptation Intention	0.196	0.058	3.379	0.001	Supported
H3	Self-efficacy → Adaptation Intention	0.215	0.056	3.839	<0.001	Supported
H4	Perceived Response Effectiveness → Adaptation Intention	0.327	0.059	5.542	<0.001	Supported
H5	Adaptation Intention → Household Adaptation Behaviour	0.654	0.049	13.347	<0.001	Supported

The results of the mediation analysis on the indirect effects of Climate Risk Perception, Environmental Knowledge, Self-efficacy, and Perceived Response Effectiveness on Household Adaptation Behaviour via Adaptation Intention are displayed in Table 9. All the indirect effects are positive and statistically significant, which supports that the Adaptation Intention is a significant mediator in the proposed structural model. In particular, the effect of Climate Risk Perception on Household Adaptation Behaviour is significantly indirect via Adaptation Intention ($\beta = 0.184$, $t = 4.182$, $p < 0.001$) and the 95% bootstrap confidence interval for the indirect effect [0.101, 0.271] does not contain zero, providing support for H6. Likewise, the factors of Environmental Knowledge positively affect Household Adaptation Behaviour through Adaptation Intention ($\beta = 0.128$, $t = 3.368$, $p = 0.001$) as indicated in H7. However, the self-efficacy also shows a significant indirect effect on Adaptation Intention ($\beta = 0.141$, $t = 3.615$, $p < 0.001$), thus supporting H8. Among the mediation paths the indirect effect of Perceived Response Effectiveness is highest ($\beta = 0.214$, $t = 4.553$, $p < 0.001$) and the 95% bootstrap confidence interval is [0.123, 0.309], supporting H9. Importantly, all of the confidence intervals do not contain 0, indicating the statistical significance of all mediation effects. These findings show that Adaptation Intention acts as an important psychological link from households' climate risk perceptions, environmental knowledge, adaptive confidence, and adaptation measure beliefs to household adaptation behaviour. The results of the overall model show that Adaptation Intention acts as a robust mediator in understanding household's decisions on climate adaptation.

Table 9. Mediation analysis results (H6–H9)

Hypothesis	Indirect Relationship	Indirect Effect (β)	Standard Error	t-value	p-value	95% Bootstrap CI	Decision
H6	Climate Risk Perception → Adaptation Intention → Household Adaptation Behaviour	0.184	0.044	4.182	<0.001	[0.101, 0.271]	Supported
H7	Environmental Knowledge → Adaptation Intention → Household Adaptation Behaviour	0.128	0.038	3.368	0.001	[0.056, 0.203]	Supported
H8	Self-efficacy → Adaptation Intention → Household Adaptation Behaviour	0.141	0.039	3.615	<0.001	[0.069, 0.221]	Supported

Hypothesis	Indirect Relationship	Indirect Effect (β)	Standard Error	t-value	p-value	95% Bootstrap CI	Decision
H9	Perceived Response Effectiveness → Adaptation Intention → Household Adaptation Behaviour	0.214	0.047	4.553	<0.001	[0.123, 0.309]	Supported

The results of the moderation analysis that explores the moderation effect of Community Resilience in the relationship of Adaptation Intention and Household Adaptation Behaviour is presented in Table 10. The results indicate that the interaction effect of Adaptation Intention and Community Resilience is positive, and statistically significant ($\beta = 0.167$, $t = 3.212$, $p = 0.001$); thus, supporting H10. This finding suggests that Community Resilience enhances the positive association between households' intentions to implement climate adaptation measures and their climate adaptation actions. That is, households in more resilient communities are more likely to convert their intention to adapt into actual adaptation action compared to households residing in less resilient communities. The effect size of the interaction term ($f^2 = 0.041$) suggested a small but meaningful moderating effect according to the guidelines suggested by Hair et al. [23], implying that the Community Resilience does not dominate the adaptation behaviour but its role as a moderator is important in improving the adaptation behaviour. Overall, the moderation analysis underlines the importance of community-level resources, institutional support, social networks and collective adaptive capacity to implement household adaptation strategies successfully, and suggests strengthening community resilience as a part of a broader climate adaptation policy.

Table 10. Moderation analysis results (H10)

Hypothesis	Relationship	β	Standard Error	t-value	p-value	Effect Size (f^2)	Decision
H10	Adaptation Intention × Community Resilience → Household Adaptation Behaviour	0.167	0.052	3.212	0.001	0.041	Supported

Table 11 shows the coefficient of determination (R^2), effect size (f^2) and predictive relevance (Q^2) of the structural model. The results show that the model has a satisfactory explanatory and predictive power. As such, the four exogenous constructs account for 63.8% of the variance in Adaptation Intention ($R^2 = 0.638$; Adjusted $R^2 = 0.632$), which is deemed as having high explanatory power following Hair et al. [23]. The order of these predictors, from largest to smallest effect size (f2) on Adaptation Intention is: Perceived Response Effectiveness (f2 = 0.174), a medium effect size; Climate Risk Perception (f2 = 0.126); Self-efficacy (f2 = 0.091); and Environmental Knowledge (f2 = 0.078), which are all small effect sizes. In addition, the model has demonstrated good predictive power as the Q^2 value is 0.438 and is far greater than zero. The structural model for Household Adaptation Behaviour has a moderate to substantial explanatory power, accounting for 58.9% of its variance (R 2 = 0.589; Adjusted R 2 = 0.583). The variable of Adaptation Intention has a high influence on the Household Adaptation Behaviour ($f^2 = 0.603$) which indicates the dominant role of Adaptation Intention in determining the actual Household Adaptation Behaviour. Community Resilience ($f^2 = 0.082$) and Adaptation Intention x Community Resilience ($f^2 = 0.041$) have small but significant effect sizes and may be adding some explanatory power to the model. The Q^2 value of 0.394 is another indicator of the structural model's adequate predictive relevance for Household Adaptation Behaviour. The findings overall validate that the proposed model has an acceptable explanatory

power, meaningful effect sizes and strong predictive relevance, which means the robustness and the adequacy of the structural model to explain household climate adaptation behaviour is justified.

Table 11. R^2, effect size (f^2), and predictive relevance (Q^2)

Endogenous Construct	Predictor	R^2	Adjusted R^2	f^2	Effect Size	Q^2
Adaptation Intention	Climate Risk Perception	0.638	0.632	0.126	Medium	0.438
	Environmental Knowledge			0.078	Small	
	Self-efficacy			0.091	Small	
	Perceived Response Effectiveness			0.174	Medium	
Household Adaptation Behaviour	Adaptation Intention	0.589	0.583	0.603	Large	0.394
	Community Resilience			0.082	Small	
	Adaptation Intention × Community Resilience			0.041	Small	

Note: R^2 represents the coefficient of determination, Adjusted R^2 accounts for model complexity, f^2 indicates the effect size of each predictor (0.02 = small, 0.15 = medium, and 0.35 = large), and Q^2 values greater than zero indicate satisfactory predictive relevance of the structural model.

5. Discussions

Results of this study give significant empirical evidence that the behavioural and cognitive aspect of climate adaptation is the most common among the household adaptation of coastal Bangladesh. In line with the proposed theoretical framework, households' adaptation intention was significantly affected by their climate risk perception, environmental knowledge, self-efficacy, and perceived response effectiveness, which further resulted in adaptation behaviour. Furthermore, adaptation intention was identified as a major mechanism between all four antecedent variables and household adaptation behaviour and community resilience also boosted the relationship between adaptation intention and behavioural implementation. These findings confirm the propositions of Protection Motivation Theory (PMT) and the Theory of Planned Behaviour (TPB), which predict that adaptation behaviour is not only a response to environmental exposure, but also a result of cognitive evaluations, perceived capabilities and supporting social environments.

H1 is supported as a positive relationship exists between climate risk perception and adaptation intention, indicating that household climate risk perception is positively associated with adaptation intention. This result is very similar to Ahmed et al. [8] who found that those farmers residing in sensitive riverine char areas implemented a higher number of adaptation strategies when they felt climate risks were high. Likewise, Mamun et al. [2] found that farmers' perception of flood, drought, river bank erosion and heat-waves had pivotal impacts on adaptation decisions. Rakib et al. [1] also found a high degree of correlation between local perceptions of climate vulnerability and the actual environmental vulnerability, suggesting that households with high climate vulnerability-perception are more likely to adopt protective actions. Shehab et al. [7] and Swarnokar et al. [5] also provide more recent evidence of this relationship, which demonstrates a positive effect of direct cyclone, salinity intrusion, and flooding exposure on households' adaptation intentions. Similarly, Freihardt [6] showed that while there can be discrepancies between perceived and actual changes in climate, perceptions of environmental change are still the key factor in driving behavioural responses to it.

This present finding is supported by these studies as a whole, which indicate that climate risk perception is the first motivational step and influences household adaptation decisions.

H2 was also positively supported, showing that environmental knowledge contributes to increased intention to adapt; thus, environmental awareness and understanding of climate change are important factors in fostering adaptive action. This result aligns with Banu et al. [19], which states that a lack of knowledge about climate change significantly obstructed the implementation of climate mitigation practices in Bangladesh. Likewise, Islam et al. [21] found a significant impact of educational status on preparedness and perception of communities for climate adaptation within the Sundarbans. Kibria et al. [10] also showed that indigenous knowledge and local adaptation technologies have a significant effect on improving the resilience of coastal households. The significance of knowledge is also evident in Sojib et al [12], where it was observed that women with high knowledge, positive attitudes, and hands-on expertise were more involved in climate adaptation efforts. All of these results indicate that knowledge can be more than just an awareness of climatic hazards and involves knowledge of what adaptation options are available, which increases households' self-confidence in the implementation of effective adaptation measures.

The strong association between self-efficacy and adaptation intention (H3) suggests that household with higher self-efficacy in coping with climate related challenges are more likely to intend adopting adaptation measures. This is quite in line with the self-efficacy dimension of Protection Motivation Theory, which suggests that people are more likely to take protective action when they feel capable of behavior. This is corroborated by the findings of Swarnokar et al. [5], which revealed that local innovation, community engagement, and household readiness boost confidence in responding to climate-driven hazards. Kibria et al. [10], on the other hand, highlighted that indigenous knowledge and locally developed technologies enhance the adaptive capacity of households, which enables them to have confidence in addressing environmental challenges. Moreover, Ahmed and Kiester [11] also showed that disparities in adaptation resources hinder the perceived ability of households—especially women—to make adaptation decisions. The result has also been consistent with the study of Tohan et al. [14] who found that households with high adaptive capacity had a greater capacity to cope with food insecurity due to climate change. These studies collectively argue that psychological confidence is an irreplaceable precondition of initiating the awareness into behavioural intention.

Perceived response effectiveness was by far the strongest predictor of adaptation intention (H4), suggesting that households may be more likely to engage in adaptive behaviours if they feel that the adaptation measures that are available will be effective in reducing risks associated with climate change. This discovery aligns well with Protection Motivation Theory and is similar to the empirical evidence found by Shehab et al. [7] that households took adaptation actions as they believed it would help mitigate disaster impact. A survey conducted by Swarnokar et al. [5] also revealed that the most common practices, such as rainwater harvesting, implementing climate-resilient farming methods, improving housing structures, growing salt-tolerant crops and disaster preparedness, were widely adopted due to their perceived effectiveness by the communities. Additionally, the significant positive effect of farmers adopting climate adaptation options on the food security scores indicated that farmers' perceptions about the effectiveness of climate adaptation options were upheld. Similarly, Banu et al., [19] found that communities with greater confidence in climate mitigation efforts experienced greater increases in implementation behaviour. Overall, these findings suggest that

households invest more in adaptation in terms of time, labour, and financial resources when they see benefits from doing so.

The strong positive correlation between adaptation intention and household adaptation behaviour (H5) validates that behavioural intention is the next and immediate step of adaptation behaviour. This result is in line with the Theory of Planned Behaviour and helps to confirm the results of earlier empirical studies which have shown that a higher intention to act leads to a higher probability of adaptive action. Ahmed et al. [8], Rahman et al. [9], Mamun et al. [2] and Shehab et al. [7] noted that the households with high motivation and willingness to adapt were more likely to adopt a diverse set of adaptation strategies. Likewise, Swarnokar et al. [5] reported that adaptive practices were widely adopted among the households who actively acknowledged the climate threat and planned to enhance their adaptation strategies. Thus, the present finding supports that the intention is a behavioural link between the cognitive evaluation and the actual household adaptation behaviour.

The mediation analysis (H6–H9) also shows that the adaptation intention is the key psychological pathway between climate risk perception, environmental knowledge, self-efficacy, and perceived response effectiveness, and household adaptation behaviour. While the direct relationship between these variables and the adaptation outcomes was found in previous studies, few studies examined the mediating role of behavioural intention between these variables and the adaptation outcome. The present findings thus complement previous studies, by providing a process of behaviour that turns cognitive factors into actions of adaptation. Results give empirical support to combine Protection Motivation Theory and the Theory of Planned Behaviour, where households evaluate climate threats, assess their knowledge and capabilities, form intentions to adapt and then actually adapt. This is a more holistic explanation than previous studies that have only investigated direct effects in a sequential behavioural process.

Lastly, a significant moderation effect of community resilience was found in the relationship between adaptation intention and household adaptation behaviour (H10), which means that household adaptation intentions were better translated into actual adaptation behaviour when the community in which they lived was more resilient. The result is found to be very consistent with the findings of Kibria et al. [10] which highlighted the role of indigenous knowledge, community involvement, and institutional support in building resilience. Likewise, Bhattacharjee et al. [3] showed that multidimensional community resilience decreases household vulnerability and increases adaptive capacity in coastal Bangladesh. Rabbani and Cotton [20] also noted that community networks and disaster preparedness enhance collective action in response to climate hazards, and Swarnokar et al. [5] emphasized the importance of local governance, infrastructure, and stakeholder engagement and cooperation in enabling adaptation. All these studies indicate that resilient communities are those with the social, institutional, informational and physical means to help households turn intentions to adapt into persistent changes in behavior. Thus, enhancing community resilience can help increase adaptive capacity, while also maximizing the effectiveness of behaviour change efforts to encourage household climate adaptation.

In sum, the findings add to the literature on climate adaptation, by showing that household adaptation behaviour is shaped by the interplay of cognitive, motivational, and community-level factors, not environmental exposure. This study brings together Protection Motivation Theory and the Theory of Planned Behaviour to provide a complete behavioural explanation of climate

adaptation in coastal Bangladesh and is complementary to the existing studies that prioritised vulnerability, migration, indigenous knowledge, livelihood diversification, disaster preparedness and resilience. The findings highlight the need for concurrent increases in climate, environmental, self-efficacy, confidence in adaptation, and community resilience for sustainable climate adaptation by vulnerable coastal households.

6. Conclusions

Despite the progress made in the study of climate change impacts on coastal livelihoods and welfare of the coastal people in Bangladesh, a better understanding of the behavioral mechanisms that underlie household adaptation is still needed. Protection motivation theory and theory of planned behaviour were used as a reference to investigate the effects of risk perception, environmental knowledge, self-efficacy, and perceived response effectiveness on household adaptation behavior via mediation through adaptation intention and moderation through community resilience. The study analyzed data gathered through surveys from 230 households in six climate-vulnerable coastal districts – Khulna, Satkhira, Bagerhat, Barguna, Patuakhali, and Bhola – and explained the cognitive and contextual factors influencing climate adaptation decisions using Partial Least Squares Structural Equation Modelling (PLS-SEM).

Results of the empirical study show that the four variables of climate risk perception, environmental knowledge, self-efficacy and perceived response effectiveness have a significant and positive effect on households' adaptation intention. Of these determinants, perceived response effectiveness was the most robust predictor, meaning that the households were more inclined to implement adaptive measures when they felt that they could be effective in reducing climate risk impacts. Moreover, intention has a significant positive role in promoting the household adaptation behaviour, suggesting its status as the proximal behavioural predecessor of adaptation. The results of the mediation analysis reveal that adaptation intention is a key psychological link that converts the cognitive factors to concrete adaptation actions. Moreover, community resilience has a positive moderating effect, which means that community resilience increases the capacity of households to turn adaptation intentions into adaptation actions. Together, these results indicate that in addition to awareness of climatic risks, confidence, knowledge, effectiveness of adaptation, and community resilience are all important to successful climate adaptation.

The study makes several important contributions to the existing climate adaptation literature. In theoretical aspects, it builds on previous studies and brings together Protection Motivation Theory and the Theory of Planned Behaviour in a single theoretical model with both direct, mediating, and moderating relationships. This study offers a more comprehensive behavioural explanation of household adaptation decisions, by explicitly including adaptation intention and community resilience in the analytical model, while earlier studies in Bangladesh have focused on vulnerability assessment, livelihood adaptation, disaster preparedness, indigenous knowledge, migration or food security. The study presents empirical evidence from the highly climate-vulnerable coastal districts of Bangladesh, adding to the scarce literature on behavioural adaptation at the household level in a developing country context. Findings also illustrate the value of behavioural theories for adaptation decision making in areas that are frequently exposed to climatic hazards and are economically and socially vulnerable.

The results have a number of practical and policy implications. First, there is a need to continue to prioritise the capacity building of climate change risk communication to raise public awareness of climate risks and drive future adaptation action by government and development organisations. Second, environmental education and awareness programmes should be scaled up, to improve the climate knowledge and understanding of households with regard to available adaptation options. Third, capacity building, technical training and financial support should be provided to boost the self-efficacy and confidence of households in taking adaptation actions. Fourth, policy makers should invest in adaptation interventions that are proven to be effective and make communities more aware of the benefits, thereby boosting perceived response effectiveness. Lastly, the overall effectiveness of household adaptation strategies can be significantly increased by actions related to strengthening community resilience through better local governance, disaster preparedness, community-based organisations, climate-resilient infrastructure, early warning systems, and institutional collaboration. Such embedded measures can have a profound impact on the adaptive capacity of coastal communities that are prone to climate change, as well as supporting the national climate change resilience and sustainable development agendas.

The study has a number of limitations and potential directions for further research. Cross-sectional study design limits causal relations over time, and future longitudinal studies would be better able to capture shifts in household adaptation behaviour over time as climate changes. The findings may also not be generalised to other parts of Bangladesh or other climatic situations, due to the use of purposive sampling and collection of data from only six coastal districts. Future research may seek to increase external validity by using probability sampling and larger, nationally representative samples. Furthermore, the present study concentrated mainly on behavioural and cognitive factors, and future studies could include other contextual factors, including institutional trust, social capital, access to climatic finance, livelihood diversification, psychological resilience, digital climatic information, or the quality of governance, among others, to better explain household adaptation choices. Comparative studies also across ecological regions or between developing countries would help to gain insights into contextual factors that affect climate adaptation.

Finally, this study highlights that effective household climate adaptation is not just about exposure to environmental hazards but is essentially influenced by behavioural intentions, cognitive assessments and community resilience. The combination of psychological and contextual approaches in one conceptual framework offers a more comprehensive understanding of adaptation behaviour in relation to climate change in coastal Bangladesh. The results emphasize that boosting risk awareness, environmental knowledge, self-efficacy, confidence in adaptation actions, and community resilience significantly enhances households' adaptation responses to climate change. These insights offer a solid basis for developing evidence-based adaptation policies and community-centred programmes for resilience for sustainable livelihoods and long-term climate resilience in Bangladesh and other climate-vulnerable developing countries.

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