Which Climate Finance Instrument Works Better in Adapting to Climate Change?

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ABSTRACT

Climate finance plays a pivotal role in adapting to climate change. However, climate specialists have recently argued that the mode of delivering the finance is also fundamental in ensuring adaptation. This study aimed at identifying the effectiveness of climate finance instruments in adapting to climate change. To examine the linkage, 515 households residing in coastal areas of Bangladesh were investigated. For data analysis a non-parametric causal mediation analysis has been used. The results of the study indicate that compared to loans, grants were more effective in adapting to climate change when mediated through climate change awareness. In addition, information and the combined policy package BCCSAP (Bangladesh Climate Change Strategy and Action Plan) significantly impacted adaptation initiatives. Consistent with existing literature, loans were found to be creating an additional burden on vulnerable communities with repayment obligations. Our findings concluded that climate change-vulnerable countries should develop their climate financing instruments, blending grants and policy instruments with a specific strategic action plan.

1. INTRODUCTION

One of the rising concerns of stakeholders, policymakers, media, and academicians refers to the developments of climate finance as an imperative mechanism to address the challenges pose by climate change [1, 2]. Climate finance primarily denotes to the means and ways through which local, national and multinational sources raise funds from public, private or substitute channels to address adaptation and mitigation initiatives to tackle the consequences of climate change [3]. It is to be noted that the amount of financing needed to tackle climate change is estimated to be an exorbitant amount. For example, developing infrastructure alone demands US$90 trillion by 2025 [4]. When this is translated to the needs of the most vulnerable developing nations, this amount is estimated to be US$14-17.5 billion per year [5].

Bangladesh, being the 7th ranked nation among the 10 most vulnerable countries of the world with regard to climate change, a substantial funding (USD 5 billion annually by 2050) is needed to tackle extreme climate events [6]. Moreover, deployment of various *financing instruments* in delivering such funds has considered to be another crucial issue in ensuring successful adaptation to climate change strategies for developing countries like Bangladesh [7]. Particularly, questions and doubts have been raised regarding whether climate funds ultimately reach the most vulnerable population [1]. Besides, biggest criticisms with regard to climate financing can be attributed in two areas—purpose and mechanism (MoF,2021; DT 2021). Most of these criticisms are focused on the way these funds are disbursed to the end users who finally use these to mitigate and adapt to climate change. Often, climate finance from developed countries providing in the form of loans are viewed negatively and termed as a climate debt trap for creating additional burden on the receiver [7]. Having this background, it is argued that a lack of evidence regarding clear understanding of effectiveness of various *financing instruments* persist in this field [8-11]. Therefore, the objective of this research is to examine the linkages between various *climate finance instruments* and climate change adaptation initiatives and, hence, identify the instrument(s) that are effective in the case of Bangladesh.

2. REVIEW OF LITERATURE

Climate change poses potential threat to world eco-system to health and socio-economic well-being of human [12]. The impacts of climate change are posing a challenge to environmental and developmental sustainability [13-15] and, the way the global temperature is rising, if not controlled, could bring serious existential threat to our planet and many species including human. The global surface temperature during 2011-2020 exceeds 1.1°C compare to 1850-1900 [12].

It is widely argued that the rise in temperature, in most cases, caused by human activities, which is predominantly greenhouse gas emission through *"...unsustainable energy use, land use and land-use change, lifestyles and patterns of consumption and production across regions"* [12]. Empirical evidence unfolds the pervasive impacts of climate change such as weather and climate extremes (e.g. heatwaves, cyclones) which results in food and water insecurity; damages to land and agricultural production; harms to coastal and ocean eco-system; risk of extinction of species; increase of climate-induced food and water borne diseases; inland flooding; displacements and, hence overall socio-economic wellbeing is endangered [12]. Acknowledging the reality of climate change and its potential threats, the international community has been advancing the climate change policy discourse starting from global scale to national and regional level for the past few decades. The major area of concern is to keep the rise in the global temperature below 2°C above at pre-industrial level, but simultaneously, discussions are there to tackle the existing climate change impacts through several mitigation and adaptation strategies for which substantial funding is necessary [3]. It is also appeared that the developing nations, who are the least contributor to the climate change, are the most sufferer of negative impacts of climate change impacts [12, 16-18]. Besides, the poor and developing nations lack the financial capacity to deal with the climate change impacts. Hence, the concept of "climate finance" primarily emanates with the idea of arranging and mobilizing the necessary funding in a justifiable manner to various nations (mostly poor and developing nations) implementing targeted mitigation and adaptation strategies and respective instruments in order to address impacts of climate change or, specifically, to achieve the goal of the Paris Agreement and relevant objectives (e.g. Kyoto Protocol) [3, 19]. Adaptation and mitigation funding primarily comes from public sources, though private and other sources of funding are acknowledged as well. Empirical evidence shows that climate finance initiatives are capable in handling adaptation and mitigation of climate risks in certain contexts [12]. The direct benefits of adaptation funding are estimated to have a DRR (Disaster Risk Reduction) leveraging ratio of 1:60 [20] which specifically means that *"...annual global investment of US$6bn in appropriate disaster risk management strategies would generate total benefits in terms of risk reduction of US$360 billion"* [21]. Acknowledging the potential benefits of adaptation strategies, over the past few decades the total financing for adaptation initiatives and mobilization pathways have been broadened but still there is a substantial gap between the actual climate funding for planned projects and the estimated costs, particularly in the developing nations [12, 22]. Recent estimation shows that around US$ 700 billion to US$ 5 trillion annual funding would be needed to address the infrastructure development initiatives in order to materialize the goals of Paris Agreement by 2030 [23]. With this target, during 2021-2022, on an average in total US$ 1.3 trillion was accounted for climate finance of which US$ 63 billion was accounted for adaptation initiatives [24]. Besides, taking into consideration the financial hardship of the developing countries, as per Paris Agreement, the developed countries jointly pledged to provide a floor of US$ 100 billion per year to the developing and poor nations in addressing climate risks [25]. In order to efficiently operationalize the funding mobilization, the convention under Paris Agreement developed a financial mechanism. It is to be noted that mobilization of external resources depends on the effectiveness of both interventions and respective mobilization-instruments in achieving respective adaptation or mitigation goals [26-28]. The major fund distributive-instruments that the financial mechanisms apply are loans & credit lines, grants and information and/or technical assistances to the recipients [26].

2.1 Loan

Loan can be concessional and non-concessional. Concessional loans are low-cost debt [28] usually provided by the donor agencies with flexible terms and conditions such as discounted market rates and longer repayment schedule [26]. It is documented that, compare to non-concessional loans, a reduction of 1.8% cost of debt coupled with more than 8 years of repayment schedule can reduce 12.7% costs for renewable energy source [29]. One of the prominent concessional funds is Climate Investment Fund (CIF) that mainly target to achieve a climate resilient and low carbon market by investing in various adaptation and mitigation projects [30]. On the other hand, private sector mostly prefers non-concessional loans as it increases their credit horizon with relatively lower transaction costs and lower risk (does not transfer ownership and contractual obligation for repayment) compare to equity finance [26]. However, loan could be a problem for developing countries that are already facing debt crisis or are financially vulnerable. It is reported that more than 30 countries out of 67 are in financial distress and, hence, non-concessional loans could pose further burden on their financial solvency [31]. Also, the leverage ratio is low for loans (both concessional and non-concessional), though it has high reliability and scaling up capacity [32, 33]. Most recent data show that, on an average during 2021-22, around US$ 76 billion has been financed as concessional loan and US$ 561 billion has been financed as non-concessional loan in the climate finance landscape [24].

2.2 Grant

Grants to be the most desirable source of fund as it does not require any repayment. In the climate finance paradigm, grants act as an important source of financing which, primarily, targeted towards adaptation projects. However, grant's usage is versatile in nature that usually implemented to cater diverse goals such as it covers research expense, breaks information barrier, reduces project risks through technical assistance, reduces capital costs, provides startup support for a project, conducts feasibility studies, increases leverage ratio and, commonly, finances any climate risk reduction or resilience enhancement project [26, 28, 33-35]. Grants can be in the form of direct financing or in the form of kind. Usually poor and developing nations are keen on receiving grants as it does not increase their financial burden, rather act as financial assistance [31]. Most recent data show that, on an average during 2021-22, around US$ 69 billion has been channeled as grants in the climate finance landscape [24]. However, there are two area of concerns of grants. Firstly, it is often argued that grants fail to incentivize the project developers [32]. Secondly, it is often challenging to utilize grants for initiatives that are subject to revenue generation or require sustainability and, thus, it is used as limited scale in initiatives such as capacity enhancement or knowledge management measures [36].

2.3 Information

Information is another form of intervention that is closely linked to optimization of climate-change mitigation and adaptation measures and fund mobilization. In case of fund mobilization, information act as cost reduction component for private climate finance investment [33]. On the other hand, proper information (or quality of information) regarding climate change and inherent risks can optimize adaptation strategies. A range of research works found that efficiency and sustainability of adaptation initiatives are closely connected to on-time communication of climate change information with certain target group (e.g., small holder farmers) [37-41]. Similarly, other research studies also found that proper information regarding climate change risk (e.g. potential flooding or change in water-levels; exposure to excessive heat; change in soil moisture) can guide (i) cropping scheduling and irrigation pattern; (ii) developing new infrastructure to be more climate change resilient; (iii) retrofitting existing infrastructure; (iv) managing/conserving natural resources etc [42]. Contrasting findings also persist regarding the role of information on adaptation measures. A study conducted on Ghana revealed no significant relation of information to adaptation initiatives [43]. From a different note, it is often argued that people have perceptual reservations about the reality of climate change risk and its potential consequences on human life. A study found out that information can break this stigma and bring positive change among people's perception regarding climate change and that may result in more responsible behavior with adaptation concept and initiatives [44]. Moreover, there are concerns regarding quality of information from developing country contexts. Allegedly, information often gets tainted due to *"less transparency, and more uncertainty attached to political, institutional and social conditions in many developing countries than in most industrialized countries"* [15, 33].

2.4 BCCSAP (Bangladesh Climate Change Strategy and Action Plan)

BCCSAP is a ten-year capacity and resilience building action plan formulated in 2008 (further revised in 2009 and 2022) to adapt to climate change [45]. Under six thematic areas: food security, disaster management, infrastructure, research, low carbon, and capacity building, various projects were financed. Approximately 490 million USD has been invested through 851 projects for climate change mitigation and adaptation [46]. It will be worthwhile to see the impact of these financing mechanisms in adapting to climate change.

2.5 Awareness

Several studies clearly delineate the connections between awareness and adaptation to climate change in various forms. It is widely accepted that a rising level of awareness to climate change results in positive embracement of respective adaptation policies [47, 48]. For example, a research conducted in Pakistan found that the farmers are well equipped to handle risks of climate change once they are aware about the climate change phenomenon [49]. The study also argued that the level of awareness also makes a difference in terms of developing capacities of the farmers while responding to climate change incidents. Ecopsychologists also reinforce the connections between mindful awareness and pro-

environmental or sustainable behavior and attitudes [50]. Hence it is fairly evident that the awareness is closely entangled with the successful materialization of adaptation initiatives. On the other hand, objective of various climate finance measures is to combat climate change risk through various adaptation and mitigation strategies. Besides, it intends to educate and develop capacities of climate risk-prone groups regarding such adaptation and mitigation initiatives where, as mentioned earlier, awareness act as an intrinsic catalyst to the process. However, there is a gap in research that explores the mediating effect of awareness while exploring the relationships between climate finance and adaptation measures. Therefore, this research has taken the initiative to examine the relationships between climate finance and adaptation measures taking awareness as mediator.

The above discussion illustrates various aspects, both positives and area of concerns, of different climate finance mechanisms/instruments. It is to be noted that the effectiveness of any adaptation strategy or intervention is closely linked to appropriate financing policy and mechanism [8]. Besides, investors, donors and any relevant party would be concerned regarding effective means of funding to cater their climate adaptation objectives. While a range of policy instruments have been developed to support climate finance models and deployment measures, still a gap exists regarding empirical evaluation of climate finance instruments and respective literature of climate finance policies that are implemented [8-11]. Hence, to address this gap, this paper has taken a modest step to explore the connections between various climate finance instruments with respect to climate change adaptation measures in the context of Bangladesh.

3. METHODOLOGY

3.1 Theoretical model

Based on the review of relevant works of literature the following theoretical model is developed (see Figure 1):
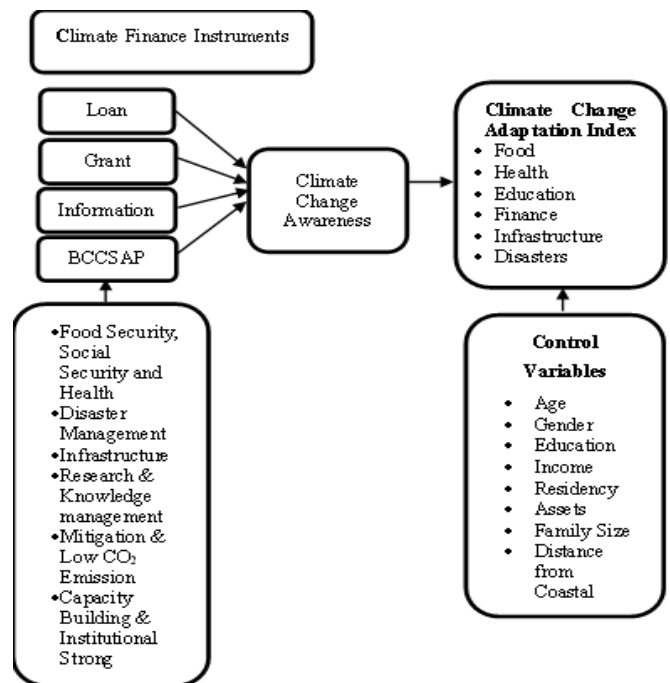

Figure 1. Theoretical model

3.2 Hypothesis

From the arguments of previous literature, it can be deduced that climate finance instruments play a major role in ensuring adaptation to climate change. For examining the effect of climate finance projects following hypothesis is developed for analysis based on the theoretical discussion above:

H_a: Climate finance instruments have significant impact on climate change adoption

To test our hypotheses, we apply Causal Mediation Analysis [50], which is grounded in the Rubin Causal Model and the potential outcomes framework. This method allows us to decompose the total effect of an independent variable on an outcome variable into:

- Average Causal Mediation Effect (ACME): the portion of the effect transmitted through the mediator variable (CCA), and
- Average Direct Effect (ADE): the portion of the effect that operates independently of the mediator.

This approach is particularly advantageous due to its non-parametric and simulation-based nature, which relies on bootstrapping to estimate the sampling distribution of the mediation effects and their associated confidence intervals. Our analysis follows a three-step procedure for each independent variable: First, we begin by estimating a linear regression where the proposed mediator to estimate the indirect effect, CCA, is regressed on the independent variable and a set of control variables:

$$CCA = f(Independent\ Variables, Control\ Variables) \qquad (1)$$

Next, we fit a second linear model in which the outcome variable to estimate the direct effect, CCAI, is regressed on the independent variable, the mediator (CCA), and the same control variables:

$$CCAI = f(Independent\ Variables, CCA, \\ Control\ Variables) \qquad (2)$$

Finally, we conduct the mediation analysis using the mediate function from the mediation package in R to estimate the total effect. This function integrates the results of the two models and estimates the ACME and ADE using 1,000 bootstrap simulations. The bootstrapped confidence intervals provide robust inference on whether the mediation effect is statistically significant.

3.3 Research approach

Mixed methods, i.e. a combination of both quantitative and qualitative methods have been applied in the study to get better insight of the scenario. The former includes questionnaire-survey approach with statistically signified number of climate finance project beneficiaries selected by stratification, while the latter entails focused blended approach, i.e., desk study on the issue, key informant interviews, focus group discussion (FGDs), discussion with project awarding and implementation agencies, experts and policymakers.

In Eq. (1), CCAI (Climate Change Adaptation Index) is taken as a dependent variable, CCA (Climate Change Awareness) taken as the Mediator Variable. To check the mediator effect, CCA and ratios of independent variables are used for making interaction terms. Details of variables are listed in Table 1.

Table 1. Variable particulars

Specification	Variables	Details	Measurement
Dependent Variable	CCAI	Climate Change Adoption Index	Measured through a developed index with stapel scale
Mediator Variable	CCA	Climate Change Awareness	Measured through 5 points Likert scale with 7 questions
Independent Variables	LOAN	Loans for dealing with climate change impacts	Here, Loan=0 means no loan is sanctioned; Measured through 5 points Likert scale with the Amount of Loan Amount
	GRANT	Grants for dealing with climate change effects	Here, Grant=0 means no grants is distributed; Measured through 5 points Likert scale
	INFO	Information or advice to deal with the effects of climate change	Here, INFO=0 means no information or advice is given; Measured through 5 points Likert scale
	BCCSAP	Bangladesh Climate Change Strategy and Action Plan	Here, BCCSAP=0 means no assistance is provided; Measured through 5 points Likert scale
Control Variables	AGE	Age of the respondent	1=18 to25, 2=26 to 35, 3=36 to 45, 4=46 to 55, 5=56 and above
	GENDER	Gender of respondent	1=Male, 2=Female
	EDU	Education of respondent	1=1 to 5, 2=6 to 8, 3=9 to 10, 4=11 to 12, 5=above HSC
	INC	Income of respondent	1=0 to 5000, 2=50001 to 10000, 3=10001 to 30000 ,4=30001 to 50000, 5=50001 and above
	RES	Time of resident at that place	1=0 to 10, 2=11 to 20, 3=21 to 30 ,4=31 to 40, 5=41 and above
	ASSET	Asset of the family	1=0 to 500000, 2=500001 to 1000000, 3=1000001 to 2000000,4=2000001 to 400000, 5=400001 and above
	FAM	Family Size	1=1 to 2, 2=3 to 4, 3=5 to 6, 4=7 to 8, 5=9 and above
	DIST	Distance from Costal Shore	1=1 to 20, 2=21 to 40, 3=41 to 60, 4=61 to 80, 5=81 and above

3.4 Sampling

Unions, which are the smallest governmental administrative unit in Bangladesh, were the primary unit of data collection. Unions are superseded by upazila (sub-district), zila (district), and bibhag (division). There are 19 districts in coastal areas of Bangladesh. Four most vulnerable districts (Barguna,

Bagerhat, Patuakhali, and Laxmipur) in the coastal belt are selected based on their proximity and vulnerability to seashore (see Figure 2). The Bangladesh Integrated Water Resources Assessment had identified 12 districts as the most vulnerable districts of Bangladesh with regard to climate change. Among these Bagerhat scores 6.2 (Very High), Patuakhali scores 5.2 (High), Barguna scores 5.0 (High) and Lakhipur scores 6.5

(Very High) vulnerability index. A total of 515 samples were collected through direct interview during the month of July to September.

3.5 Survey instrument

Climate Change Adaptation Index (CCAI) has been calculated by using staple scale that was used to distinguish between areas having negative, low and high CCAI. Staple scale also produces interval data same as Likert, Semantic Differentials (SD) and numerical scales [51]. Negative scores were assigned for very low level of adaptation. Positive scores were assigned for going beyond the minimum standard. Whereas, high positive scores were awarded for having very high level of adaptation (see Table 2). The survey instrument used contained questions divided in categories shown in Table 2. Pre-testing was conducted to test and validate the survey instrument before the final survey (Table 3). Modifications were done with regard to the indicators of CCAI based on the findings of the pre-testing.
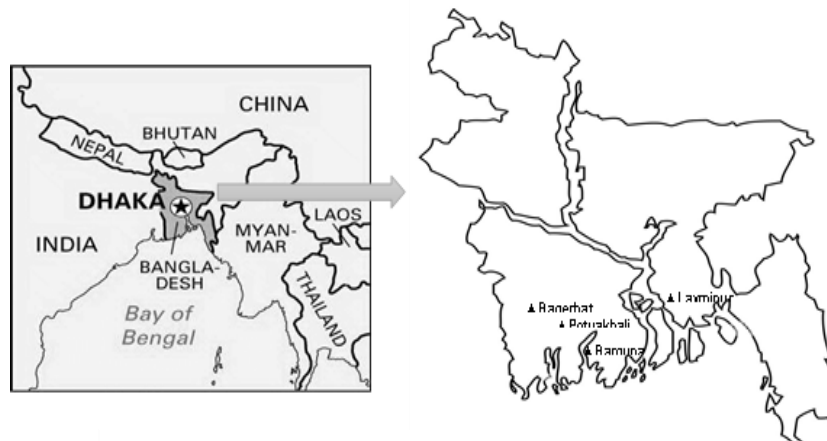

Figure 2. Study area

Table 2. An example question of scoring

Dimensions	Category	Degree of Adaptation	Scores	Explanation
Health	**Hospital**	1. Hospitals and medical care facilities are not available	-5	Access to health care is tough
		2. Hospitals and medical care facilities are available within 30 minute walk	-3	Access to health care is difficult
		3. Hospitals and medical care facilities are available within 10 minute walk	0	Got access to health care
		4. Medical staff visits the household regularly	+3	Got convenient access to health care
		5. Hospitals and medical care facilities are available in the household in case of emergency	+5	Health care and medical supplies are ensured

Table 3. Content of the survey instrument

Household Basic Information
Survey instrument included basic information of the household such as: number of members, gender, age, education, income; asset holding
Awareness on Climate Change
Survey instrument included questions on familiarity with climate change terms, loss and benefits of climate change
Climate Change Intervention
Survey instrument included questions on receipt of cash, kind or information support to adapt to climate change in the form of loan or grant in BCCSAP (Bangladesh Climate Change Strategy and Action Plan) specified categories
Climate change Adaptation Index
Survey instrument included questions on climate change adaptation in six categories: food, health, education, finance, infrastructure, disasters

4. FINDINGS

4.1 Descriptive statistics and normality test

Table 1 shows the variable particulars, whereas Table 4 illustrates the descriptive statistics and Normality test results of the data collected. The descriptive statistics shows that the mean value of Climate change Adoption Index (CCAI) is-24.91, this indicates that there is a very low degree of adoption to climate change in the sampled coastal areas of Bangladesh. The mean value of Climate change awareness (CCA) is 2.5 out of 5, that indicates that on an average 50% of sampled population is aware about the climate change. Furthermore, the mean value of Loan is 0.33 that indicates that on an average only 6.6 % got loan to deal with climate change issues. The values of standard deviations of all values are very low except the CCAI. This indicates that opinions of the sampled population do not vary too much.

Table 4. Results of descriptive statistics and normality test

Variables	N	Mean	Median	Std.	Min	Max	Skew.	Kurt.	Shap.W.
CCAI	515	-24.91	-28.00	19.73	-78.00	44.00	0.74	0.61	0.95
CCA	515	2.50	2.29	0.78	1.00	5.00	0.35	-0.09	0.98
LOAN	515	0.33	0.00	0.88	0.00	4.00	2.62	5.81	0.42
GRANT	515	1.16	1.00	1.09	0.00	4.00	0.35	-0.79	0.80
INFO	515	1.17	1.00	0.69	0.00	3.50	0.77	0.25	0.95
BCCSAP	515	2.20	2.50	0.98	0.00	3.76	-1.19	0.66	0.85
AGE	515	3.51	3.00	1.08	1.00	5.00	-0.05	-1.00	0.89
GENDER	515	1.04	1.00	0.19	1.00	2.00	4.93	22.37	0.18
EDU	515	1.51	1.00	0.94	0.00	5.00	1.89	3.10	0.62
INC	515	2.29	2.00	0.76	1.00	5.00	-0.14	-0.22	0.82
RES	515	3.19	3.00	1.35	1.00	5.00	-0.08	-1.22	0.89
ASSET	515	1.91	1.00	1.36	1.00	5.00	1.36	0.54	0.68
FAM	515	2.56	2.00	0.74	1.00	4.00	0.31	-0.43	0.83
DIST	515	2.97	1.00	2.00	1.00	5.00	0.04	-2.01	0.64

Note: Std.=Standard Deviation, Skew.=Skewness, Kurt.=Kurtosis, Shap.W.=Shapiro Wilk test of Normality

However, the skewness values indicate that most of the variables are positively skewed, with the exception of CCA, GRANT, AGE, INCOME, and EDUCATION. The kurtosis statistics further suggest that the distribution of most variables does not exhibit extreme tail behaviour, except for LOAN and GENDER, which display characteristics of fat-tailed distributions. To address potential biases arising from these distributional features, we adopt a non-parametric mediation analysis with bootstrapping, which does not rely on normality assumptions and provides more robust inference. Additionally, in the subsequent regression analyses, we employ robust standard errors to account for potential heteroscedasticity and improve the reliability of our coefficient estimates. Nevertheless, here Shap.W. indicates the Shapiro Wilk test of Normality. The null hypothesis of the Shapiro Wilk test indicates that data are normally distributed and at the 5% level of significance all null hypotheses are accepted. This indicates that all variables have normal distribution. The results of descriptive statistics suggest that these data can be taken into consideration for further analysis.

4.2 Correlation analysis

Before moving forward to the regression analysis, it is important to check the correlation between variables. The results of Pearson correlation test are demonstrated in Table 5. Results indicate that there is positive significant relationship in between Dependent variable Climate Change Adoption Index (CCAI) and Climate Change Awareness (CCA), GRANT, BCCSAP, Education (EDU), Asset, Family Size (FAM). However, loan, gender, and distance from coastal areas (DIST) have negative significant relationships. From descriptive statistics the median of loan was found to be zero and accordingly negative significance found in the correlation analysis is a consistent result. Similarly, when the distance increases from coastal shore, adoption to climate change would be less [52]. These results signal a positive nod for moving forward to regression analysis to test the developed hypothesis.

4.3 Regression analysis

First, we begin our analysis by examining indirect effects. Table 6 presents the results from the indirect effect models, where Climate Change Awareness (CCA) serves as the dependent variable across all four model specifications. Each model examines the impact of one key independent variable on CCA while controlling for the same set of covariates. In Model 1.1, the variable LOAN shows a statistically significant and positive effect on CCA (β=0.197, p<0.001), suggesting that access to loans for climate-related impacts is associated with increased awareness. Model 1.2 indicates a similarly strong and positive association between GRANT and CCA (β=0.303, p<0.001), highlighting the role of financial support mechanisms in raising climate change awareness. Conversely, Model 1.3 reveals a negative and significant relationship between INFO and CCA (β=-0.221, p<0.001), implying that information or advice received may be ineffective or potentially overwhelming, thus reducing perceived awareness. Lastly, Model 1.4 shows that awareness of the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) significantly increases CCA (β=0.306, p<0.001), emphasizing the importance of formal policy communication.

Table 5. Results of correlation coefficient analysis

| Variables	CCAI	CCA	LOAN	GRANT	INFO	BCCSAP	AGE	GENDER	EDU	INC	RES	ASSET	FAM	DIST
CCAI	1													
CCA	0.32**	1												
LOAN	-0.15**	0.27**	1											
GRANT	0.21**	0.38**	0.07	1										
INFO	-0.02	-0.20**	0	-0.40**	1									
BCCSAP	0.21**	0.44**	0.17**	0.25**	-0.05	1								
AGE	-0.01	0.10*	0.07	0.10*	0.10*	0.11*	1							
GENDER	-0.14**	-0.04	0.05	0.05	-0.10*	0.03	-0.05	1						
EDU	0.27**	0.43**	-0.01	0	0	0.06	-0.05	-0.05	1					
INC	-0.08	0.06	0.02	-0.01	-0.20**	-0.13**	-0.23**	-0.26**	0.15**	1				
RES	0.01	0.13**	-0.06	0.16**	-0.13**	0.12**	0.45**	-0.02	0.09	-0.13**	1			
ASSET	0.35**	0.35**	-0.01	0.10*	-0.06	0.06	0.21**	-0.08	0.43**	0.10*	0.20**	1		
FAM	0.03	-0.04	0.03	-0.17**	0.20**	-0.11*	0.12**	-0.13**	-0.01	0.05	0.04	0.05	1	
DIST	-0.53**	0.06	0.37**	-0.20**	0.36**	0.05	0.11*	0.05	-0.07	0	-0.08	-0.17**	0.14**	1
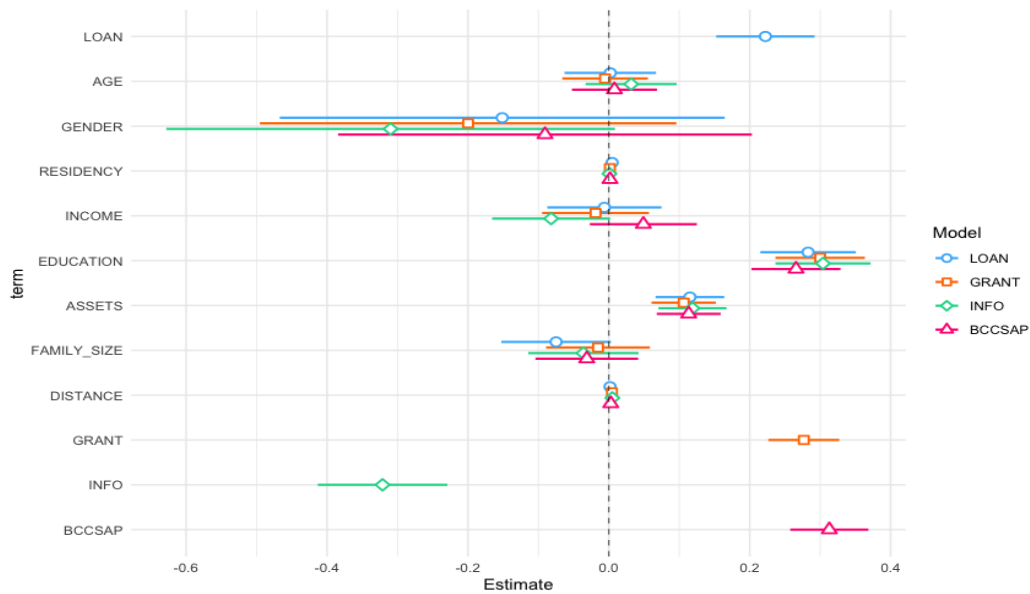
Figure 3. Standardized beta coefficients for indirect effect

Table 6. Indirect effect model results

	Model 1.1	Model 1.2	Model 1.3	Model 1.4
	CCA	CCA	CCA	CCA
(Intercept)	2.504***	2.506***	2.510***	2.502***
	(0.030)	(0.028)	(0.030)	(0.028)
LOAN	0.197***			
	(0.031)			
AGE	0.002	-0.006	0.034	0.009
	(0.038)	(0.034)	(0.038)	(0.037)
GENDER	-0.151	-0.200	-0.310*	-0.091
	(0.137)	(0.119)	(0.128)	(0.125)
RESIDENCY	0.077*	0.024	0.014	0.027
	(0.033)	(0.032)	(0.035)	(0.033)
INCOME	-0.005	-0.014	-0.062 *	0.037
	(0.031)	(0.028)	(0.030)	(0.028)
EDUCATION	0.265***	0.282***	0.285***	0.249***
	(0.034)	(0.033)	(0.034)	(0.034)
ASSETS	0.156***	0.144***	0.161***	0.154***
	(0.032)	(0.030)	(0.032)	(0.029)
FAMILY_SIZE	-0.056	-0.011	-0.027	-0.023
	(0.028)	(0.027)	(0.030)	(0.027)
DISTANCE	0.069*	0.182***	0.206***	0.112***
	(0.035)	(0.028)	(0.032)	(0.027)
GRANT		0.303 ***		
		(0.025)		
INFO			-0.221***	
			(0.036)	
BCCSAP				0.306***
				(0.031)
N	515	515	515	515
R2	0.314	0.399	0.323	0.405
Mean VIF	1.273	1.247	1.297	1.242

Note: All continuous predictors are mean-centered and scaled by 1 standard deviation. The outcome variable is in its original units. Standard errors are heteroskedasticity robust. ***p<0.001; **p<0.01; *p<0.05.

All models exhibit good explanatory power, with R-squared values ranging from 0.314 to 0.405. The mean Variance Inflation Factor (VIF) values, which range between 1.242 and 1.297, suggest no serious multicollinearity issues among the predictors. Figure 3 presents the standardized beta coefficients for the indirect effect models, providing a comparative view of the strength and consistency of predictors across different model specifications. The results indicate that, for mostvariables, the standardized coefficients lie within similar confidence intervals, suggesting a stable relationship between the independent variables and the mediator, Climate Change Awareness (CCA). However, a notable exception is observed in the case of GENDER, where greater variability in the coefficient is evident. This suggests that gender may play a more heterogeneous role in shaping climate change awareness, potentially influenced by underlying social, cultural, or informational disparities. Overall, these findings provide initial support for the role of financial and policy-based interventions in shaping climate change awareness, a key mediating factor in the broader framework of climate adaptation behaviour.

Interestingly, INFO in Model 2.3 exhibits a significant and positive direct effect (β=3.957, p<0.001), indicating that access to climate-related information not only enhances awareness but also directly encourages adaptive behaviour. In Model 2.4, familiarity with BCCSAP also demonstrates a significant positive effect on CCAI (β=2.709, p<0.001), suggesting that national-level policy initiatives can directly influence individual adaptation decisions. The models exhibit relatively strong explanatory power, with R-squared values ranging from 0.501 to 0.529, indicating that over 50% of the variance in adaptation behaviour is explained by the predictors. The mean VIF values remain low (between 1.327 and 1.366), confirming the absence of multicollinearity concerns. Figure 4 illustrates the standardized beta coefficients for the direct effect models, offering a visual representation of the relative influence of predictors on Climate Change Adoption Index (CCAI). Across all models, the standardized coefficients largely fall within similar confidence interval, indicating consistent effects across different specifications. However, GENDER once again displays greater variability compared to other predictors. This pattern aligns with the results observed in the indirect effect models, suggesting that gender plays a more nuanced and potentially context-dependent role in shaping both climate awareness and adaptive behaviour. These findings provide strong support for the theoretical framework that climate awareness plays a crucial mediating role, while certain variables like information and policy awareness can also exert a direct influence on adaptive behaviour.
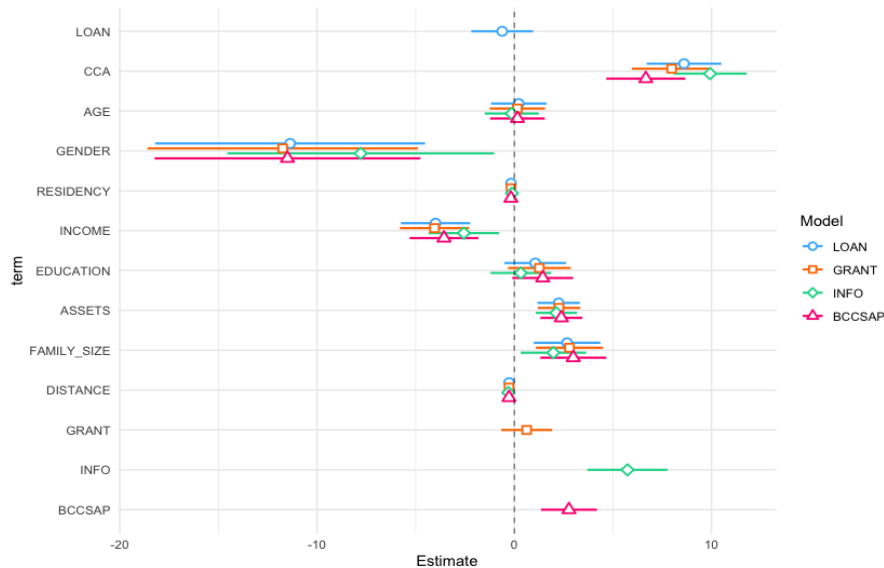
Figure 4. Standardized beta coefficients for direct effect

Table 7. Direct effect model results

	Model 2.1	Model 2.2	Model 2.3	Model 2.4
	CCAI	CCAI	CCAI	CCAI
(Intercept)	-24.489 ***	-24.476 ***	-24.621 ***	-24.484 ***
	(0.643)	(0.642)	(0.624)	(0.632)
LOAN	-0.542			
	(0.897)			
CCA	6.696***	6.210***	7.727***	5.189***
	(0.731)	(0.808)	(0.758)	(0.800)
AGE	0.246	0.169	-0.141	0.175
	(0.752)	(0.751)	(0.726)	(0.731)
GENDER	-11.364 ***	-11.742 ***	-7.788*	-11.501 ***
	(3.223)	(3.247)	(3.163)	(3.171)
RESIDENCY	-2.661***	-2.655***	-1.890**	-2.783***
	(0.730)	(0.719)	(0.703)	(0.709)
INCOME	-3.037***	-3.079***	-1.947**	-2.711***
	(0.720)	(0.728)	(0.712)	(0.709)
EDUCATION	0.997	1.192	0.311	1.353
	(0.796)	(0.810)	(0.809)	(0.771)
ASSETS	3.048***	3.075***	2.889***	3.234***
	(0.819)	(0.817)	(0.799)	(0.808)
FAMILY_SIZE	1.993**	2.083**	1.475*	2.225***
	(0.637)	(0.644)	(0.631)	(0.626)
DISTANCE	-10.902 ***	-10.938 ***	-12.386 ***	-11.125 ***
	(0.714)	(0.743)	(0.770)	(0.683)
GRANT		0.687		
		(0.796)		
INFO			3.957***	
			(0.784)	
BCCSAP				2.709***
				(0.771)
N	515	515	515	515
R2	0.501	0.501	0.529	0.515
Mean VIF	1.327	1.351	1.366	1.341

Note: All continuous predictors are mean-centered and scaled by 1 standard deviation. The outcome variable is in its original units. Standard errors are heteroskedasticity robust. ***p<0.001; **p<0.01; *p<0.05.

Table 7 reports the results of the direct effect models, where Climate Change Adoption Index (CCAI) is the dependent variable. Each model evaluates the direct impact of one key independent variable on CCAI while accounting for the mediator, Climate Change Awareness (CCA), and control variables. Across all models, CCA consistently shows a strong and statistically significant positive effect on CCAI. This underscores the central role of climate change awareness in shaping adaptive behavior, with standardized coefficients ranging from 5.189 to 7.727 (all p<0.001), confirming that higher awareness substantially increases the likelihood of adopting climate-resilient practices.

In Model 2.1, the variable LOAN does not have a statistically significant direct effect on CCAI (β=-0.542, p>0.1), suggesting that the influence of loan access on adaptation is primarily mediated through awareness. Similarly, GRANT in Model 2.2 shows a positive but non-significant effect (β=0.687), reinforcing the notion that financial assistance may indirectly affect adaptation through increased awareness.

Finally, we conducted a causal mediation analysis using 1,000 bootstrap simulations to assess the mediating role of Climate Change Awareness (CCA) in the relationship between climate-related interventions and adaptation behaviour, measured by the Climate Change Adoption Index (CCAI), following the framework [50]. The analysis investigates whether Climate Change Awareness (CCA) serves as a significant mediator in the relationship between key policy and financial instruments—LOAN, GRANT, INFO, and BCCSAP—and the Climate Change Adoption Index (CCAI). The results are presented in Table 8 and Figure 5, which report the Average Causal Mediation Effects (ACME), Average Direct Effects (ADE), and Total Effects along with 95% confidence intervals. Importantly, across all four models, the ACME, ADE, and Total Effects are statistically significant at the 1% level, indicating that both the mediated and direct pathways contribute meaningfully to climate adaptation behaviour. This robust significance across the models highlights the multifaceted nature of adaptation, where awareness and direct access to resources or information work in tandem to influence behavioural outcomes.For the LOAN variable, the indirect effect (ACME=1.912, 95% CI: 1.259 to 2.687) is significant, while the direct effect (ADE=–0.613, 95% CI: –2.560 to 1.373) is also statistically significant but negative. Thus, access to climate-related loans increased CCAI by 1.912 units via increased awareness and had a total effect of 1.299 units. This suggests that the primary channel

through which access to loans influences climate adaptation is through raising awareness. It may be the case that individuals who receive loans are more likely to engage with institutions, attend climate-related trainings, or participate in community-based programs that enhance their awareness. Interestingly, the small negative direct effect might reflect inefficiencies in loan utilization or burdens associated with loan repayment that may counterbalance their direct utility for adaptation in some contexts. In the case of GRANT, both the mediated (ACME=2.208, 95% CI: 1.624 to 2.890) and direct effects (ADE=0.628, 95% CI: –0.752 to 2.004) are statistically significant, although the direct effect is smaller. Thus, grants increased CCAI by 2.208 units through awareness and had a total effect of 2.837 units. This indicates partial mediation, where grants not only enhance awareness but also directly enable adaptive actions. Grants may come with informational components or eligibility criteria that require participation in awareness-building activities. At the same time, grants may directly support the purchase of climate-resilient inputs, infrastructure, or services. This dual mechanism emphasizes the importance of designing grant programs that are both financially supportive and educationally enriching. The INFO variable reveals a more complex mediation pattern. The indirect effect is negative and significant (ACME=–3.189, 95% CI: –4.512 to –2.182), while the direct effect is strongly positive and significant (ADE=5.743, 95% CI: 3.638 to 7.996). Thus, Climate-related information reduced CCAI by 3.189 units via a negative awareness effect but still increased CCAI by 2.553 units in total, due to a strong direct effect. This represents a suppression effect, where the information provided may reduce individuals' perceived awareness—potentially due to confusion, overload, or mistrust—yet still positively drives adaptive behaviour. This finding suggests that while information provision can motivate action, it may also generate uncertainty or anxiety that undermines confidence in one's knowledge. The implication is that information campaigns need to be carefully crafted in terms of content, delivery, and audience targeting to ensure they empower rather than confuse recipients. Lastly, for BCCSAP, both the indirect (ACME=2.087, 95% CI: 1.471 to 2.789) and direct effects (ADE=2.773, 95% CI: 1.291 to 4.211) are positive and statistically significant, indicating complementary mediation. Therefore, awareness of the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) increased CCAI by 2.087 units through awareness and had a total effect of 4.861 units. Awareness of the Bangladesh Climate Change Strategy and Action Plan appears to simultaneously increase climate awareness and directly influence adaptive actions. This suggests that national-level policy frameworks, when effectively communicated, can play a crucial role in both informing citizens and legitimizing adaptation efforts at the household or community level. The strength of both pathways demonstrates that policy visibility and accessibility are critical in driving climate-responsive behaviour. The consistent significance of all mediation and direct effects across models reinforces the central importance of Climate Change Awareness as a mechanism that links various interventions to actual behavioural change. Financial support (LOAN, GRANT), informational inputs (INFO), and policy visibility (BCCSAP) all contribute to adaptation, but their effectiveness is greatly enhanced when individuals are aware, informed, and confident in their understanding of climate risks and responses. These findings suggest that integrating awareness-building efforts into climate adaptation

programs—whether financial, educational, or policy-driven—can substantially amplify their impact. Moreover, the differential patterns across variables emphasize the need for tailored intervention strategies. For example, while grants benefit from a dual pathway, loans may require additional capacity-building to maximize their potential. Similarly, information campaigns should be re-evaluated to avoid counterproductive outcomes, and policy outreach should continue to be strengthened to reinforce both knowledge and action.
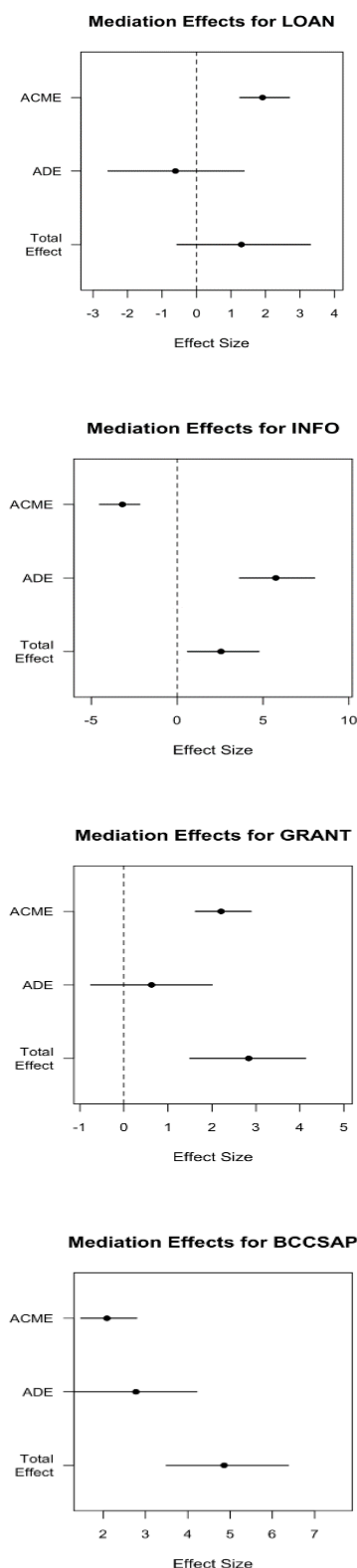

Figure 5. Mediation analysis results

Table 8. Mediating effect results

Variable	ACME	ADE	Total Effect	Sig Mediation
LOAN	1.912 (1.259, 2.687)	-0.613 (-2.560, 1.373)	1.299	Yes (p<0.01)
GRANT	2.208 (1.624, 2.890)	0.628 (-0.752, 2.004)	2.837	Yes (p<0.01)
INFO	-3.189 (-4.512, -2.182)	5.743 (3.638, 7.996)	2.553	Yes (p<0.01)
BCCSAP	2.087 (1.471, 2.789)	2.773 (1.291, 4.211)	4.861	Yes (p<0.01)

Note: Results are based on 1000 bootstrap simulations

5. DISCUSSION

The results of the study showed that BCCSAP and grants, having total effect of 4.86 and 2.84 units, respectively, in climate change adaptation via awareness, is more effective than loan or information as climate finance instruments. Overall, the findings of the study are consistent with observations in other studies where climate finance in the form of loans had been criticized for being less effective [7, 26, 31, 32].

About 80% of climate financing flows in terms of loans for mitigation measures such as renewable energy [7]. Suppliers of funds are interested in loans for mitigation as these have specific repayment conditions supported by income streams. However, as found in the study, grants and mixed instrument portfolios like BCCSAP contribute more to climate change adaptation as loans create debt distress among households already burdened with the hardship of livelihood due to climate change [31]. For example, adapting to floods requires financing in the form of grants, as these cannot generate income directly. The nonavailability of grants forces households to go for conditional loans for the prospect of getting finance, which eventually pushes them into a climate debt trap due to uncertain futures and repayment caveats [7, 31].

The negative indirect effect (-3.19 units) of information on climate change adaptation is consistent with the findings in Ghana, where no significant relationship was found between information and adaptation [43]. Whereas, overall positive effect (2.55 units) of the same is consistent with the findings of other studies in deciding adaptability [37, 39, 42, 53, 54]. In Bangladesh, information dissemination is transformative while channelled towards adaptation through awareness. Various climate change adaptation information and awareness-building campaigns by NGOs and the government proved vital in preparing for tackling climate change. However, care should be taken to ensure that this instrument is used for achieving adaptation rather than creating confusion, anxiety or materializing political agenda of the power groups [33]. Mainstreaming climate finance planning through BCCSAP in the national legal and policy framework involving 25 ministries and divisions for need-based allocation also paid rich dividends in adapting to climate change [55]. Adaptation increased 4.86 units via climate change awareness due to increased support through BCCSAP. Recently, BCCSAP has been revised to increase the thematic areas to eleven to expand the focus on natural resource management, gender, and the urban dimension of climate change [46].

Significant predictability power of the control variables: age, gender, residency, income, education, assets, family size, and distance indicate that the socio-economic background of the respondents has a significant influence in deciding adaptability in addition to climate finance. Among the control variables, gender showed greater variability. Women being more responsive and adaptive to climate change is relatable to other studies. In general, women, along with children, are the most vulnerable to climate change impacts and take more active initiatives and leadership in climate change adaptation [56]. Similar to the experience of micro-credit success stories in Bangladesh, policymakers should design climate finance products targeting women especially to achieve better adaptability. The inclusion of gender in the revised thematic portfolio of BCCSAP is expected to contribute towards this goal [46].

The significance of distance as a control variable and the fact that it is negatively correlated with adaptation were other important contributions of this study. Respondents living near the seashore are naturally more aware of climate change, receive more funds, and are more adapted than those living far from the sea. However, people living far from the sea shore but closer to river are also heavily impacted by climate change, as hundreds of rivers crisscross the whole country. Policy measures should be formulated to include them under the umbrella of climate finance.

In the domain of climate finance and adaptation, this study has significant implications for scholars, practitioners and policymakers. From the theoretical perspective of climate change, this study has definitely broadened the understanding of the impacts of climate finance instruments in adapting to climate change in the context of a vulnerable developing country. The findings of the study will help scholars to enrich theories of planned adaptation by balancing importance of soft finance mode to achieve higher degree of adaptability to climate change [46]. More importantly, not the amount of finance but the instrument of distribution that ultimately matters in determining the effectiveness of climate finance in adapting to climate change.

The findings of the study have implications for practitioners and policymakers in connecting the recent debate between developed and developing countries. While making climate finance pledges, developed countries need to decide the priority: adaptation and mitigation of climate change or commercial viability of the project. Relying on loans as an instrument for distributing climate finance may ensure the borrower's accountability to deliver; however, it comes with the caveat of additional debt burden to the already vulnerable households [32]. Developing a mixed portfolio of various financial instruments, such as grants and loans merged with targeted themes of BCCSAP might be a beneficial option for international donor agencies like Green Climate Fund (GCF) and Climate Investment Funds (CIF) to consider for achieving better adaptation [57].

Despite having robust significant results, this study is not free from limitations. The first and foremost limitation of this research is the limited coverage of the study area. Due to COVID-19 restrictions and other logistic issues, only four coastal districts could be covered by this study. Thus, the results cannot be generalized to all the coastal districts of Bangladesh. Second, though enough care was given in designing the survey instrument questions, the results of the study might still be subjected to recall and self-perception biases common to self-reported studies. A follow-up study with a large sample size and data validation is needed to draw

6. CONCLUSION

In this paper, the effectiveness of climate financing instruments was evaluated in adapting to climate change. To do so, both quantitative and qualitative techniques were applied. Questionnaire survey was conducted in four coastal districts of Bangladesh. Finally, several models were constructed to see the impact of instruments in enabling adaptability among the residents. Results of the study revealed that, climate change adaptation has a positive and significant relationship with climate financing instruments when mediated through climate awareness. Among the instruments of climate finance, grants and information were found to be the most effective. Loan creates a sense of pressure and burden on the residents because of the vulnerable nature of livelihood in the region. Findings of the study would be thought provoking for the theorists, practitioners and policymakers by adding insights into adaption theory and practice. Looking ahead, vulnerable countries should develop their own financing instruments by blending features of grants, information, and strategic action plans to fit with adaptation themes of the local context.

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