



Psychometric properties and factorial invariance of the Climate Change Attitude Survey in the Chilean population

Propiedades psicométricas e invarianza factorial de la Escala de Actitudes hacia el Cambio Climático en población chilena

Propriedades psicométricas e invariância fatorial da Escala de Atitudes em relação às Mudanças Climáticas na população chilena

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Data availability:

The dataset supporting the results of this study is not available.



Abstract: The aim of this study is to evaluate the psychometric properties and factorial invariance of the Climate Change Attitude Scale (CCAS). Based on Planned Behavior Theory, the scale measures both beliefs and behavioral intentions towards climate change. The original instrument consists of 15 items, using a five-point Likert response format. It was applied to a non-probabilistic sample of 800 Chilean participants. After translation and review, the scale demonstrated adequate content validity. A Confirmatory Factor Analysis (CFA) validated the instrument's suitability, which was adjusted to 13 items while maintaining its original two-factor structure. The invariance analysis confirmed that the bidimensional structure is not affected by gender. Evidence was found of convergent and discriminant validity, as well as adequate reliability in both dimensions. In conclusion, we support use of the Spanish version of the CCAS in Spanish-speaking communities, thus strengthening climate change research in the region from a psychosocial perspective. **Keywords:** attitude; climate change; validity; factorial invariance; reliability

Resumen: El objetivo de este estudio fue evaluar las propiedades psicométricas y la invarianza factorial de la Escala de Actitudes hacia el Cambio Climático (EACC). Diseñada con base en la Teoría de la Acción Planificada, la escala mide tanto las creencias como la intención de conducta hacia el cambio climático. El instrumento original consta de 15 ítems, con un formato de respuesta tipo Likert de cinco opciones. Se aplicó a una muestra no probabilística de 800 participantes chilenos. Después de su traducción y revisión, la escala mostró una adecuada validez de contenido. Un Análisis Factorial Confirmatorio (AFC) validó la idoneidad del instrumento, ajustado a 13 ítems, manteniendo su estructura original de dos factores. El análisis de invarianza factorial confirmó que la estructura bidimensional no se ve afectada por el género. Se encontraron evidencias de validez convergente y discriminante, así como una confiabilidad adecuada en ambas dimensiones. En conclusión, se respalda el uso de la versión en español de la CCAS en comunidades hispanohablantes, lo que fortalece la investigación sobre el cambio climático en la región desde una perspectiva psicosocial.

Palabras clave: actitud; cambio climático; validez; invarianza factorial; confiabilidad

Resumo: O objetivo deste estudo foi avaliar as propriedades psicométricas e a invariância fatorial da Escala de Atitudes em relação às Mudanças Climáticas (EAMC). Baseada na Teoria da Ação Planejada, a escala mede tanto as crenças quanto as intenções comportamentais em relação às mudanças climáticas. O instrumento original possui 15 itens, com um formato de resposta tipo Likert de cinco opções. Foi aplicado a uma amostra não probabilística de 800 participantes chilenos. Após sua tradução e revisão, a escala demonstrou validade de conteúdo adequada. Uma Análise Fatorial Confirmatória (AFC) validou a adequação do instrumento, ajustado para 13 itens, mantendo sua estrutura original de dois fatores. A análise de invariância fatorial confirmou que a estrutura bidimensional não é influenciada pelo gênero. Foram encontradas evidências de validade convergente e discriminante, bem como uma confiabilidade adequada em ambas as dimensões. Em conclusão, respalda-se o uso da versão em espanhol da EAMC em comunidades de língua espanhola, fortalecendo a pesquisa sobre mudanças climáticas na região a partir de uma perspectiva psicossocial.

Palavras-chave: atitude; mudanças climáticas; validade; invariância fatorial; confiabilidade

According to the 2022 report by Group II of the Intergovernmental Panel on Climate Change (IPCC), climate change (CC) poses a significant risk to human development. Given this scenario, it is crucial that behavioral sciences focus their efforts on analyzing sustainable attitudes, behavior and lifestyles (Corral-Verdugo, 2021).

In this context, behavioral sciences are fundamental to unravelling two psychosocial aspects related to coping with CC (Gifford, 2014; IPCC, 2022). The first are the *mitigation strategies* aimed at reducing its impact and the second are the psychological factors influencing *capacities to adapt* to extreme weather events (Nielsen et al., 2021; Sapiains & Ugarte, 2017a). Clayton (2019) stresses that understanding how attitudes and perceptions influence the adoption of sustainable behavior is crucial to addressing CC. She also argues that psychology can help overcome cognitive barriers preventing a clear perception of the problem and foster resilience through collective action and lifestyle changes (Clayton, 2024).

Psychological research on socio-cognitive and dispositional factors that influence adaptive responses to CC is at an early stage in the Latin American Literature (Sandoval-Obando & Sandoval-Díaz, 2024; Sandoval-Díaz et al., 2024; Sapiains et al., 2024; Vidal Cobo et al., 2021). Despite its importance, it remains a minority field within Latin American psychology (Medina-Arboleda, 2022). This incipient development underscores the importance of culturally relevant studies that are adapted to the regional context (Adger, 2001; Grothmann & Patt, 2005).

One of the main priorities is to make progress with the development and validation of appropriate psychometric surveys to measure attitudes and behavior toward CC. The process is still in the early stages in Latin America (Corral-Verdugo, 2021; Medina-Arboleda & Páramo, 2024; Sapiains & Ugarte, 2017a; Sandoval-Díaz et al., 2021), reflecting the lack of instruments that accurately capture the particularities of the regional context. This deficit coincides with the findings of Forero et al. (2014), who noted that just 7.7 % of social research in the region uses quantitative methods, which underscores the need to strengthen methodological rigor in future studies, especially in the validation of instruments that allow measuring the socio-cognitive factors related to adapting to CC more precisely.

The urgent need to adapt and develop culturally and contextually relevant research instruments is especially evident in the case of Chile, considering its high vulnerability to CC. Though Chile has been identified as among the Latin American countries with an advanced public perception of climate variability (Azócar et al., 2021; Chilean Ministry of the Environment [MMA], 2017), there is a persistent gap in the scientific literature regarding the identification and characterization of the psychosocial dimensions that modulate coping behavior (MMA, 2018; Sapiains et al., 2021; Sapiains et al., 2024). In this context, it is fundamental that research focus on attitude constructs, as they not only provide a framework for understanding individual assessments of the socio-environmental environment, but also provide indicators on the willingness to undertake actions in favor of the environment (Hidalgo & Pisano, 2010; Masud et al., 2015; Sierra-Barón & Millán-Otero, 2024).

Attitudes Toward Climate Change

There is abundant literature analyzing the relationship between attitudes and the intention of pro-environment behavior (Kollmuss & Agyeman, 2002; Maiteny, 2002). In the area of psycho-social studies on CC, three main explanatory models can be distinguished (Sapiains & Ugarte, 2017b).

The first model, known as Normative Influence on Altruism (Schwartz, 1977), is frequently applied in research on environmentalist behavior and argues that feelings of obligation and moral commitment are crucial factors influencing such behavior.

The second model, the Value-Belief-Norm theory of environmentalism (Stern et al., 1999), is largely based on the previous model. It suggests that environmentalist behavior derives from a combination of values, environmental beliefs, awareness, responsibility and personal or moral norms, with the latter being especially determinant.

The third model is Planned Action Theory, developed by Ajzen (1991), which holds that the intention of engaging in specific behavior is influenced by three components: i) *attitudes*, which are assessments of the objective behavior; ii) *subjective norms*, related to the expectations and pressures of the social group one belongs to; and iii) *perception of control*, which refers to the belief in the ability to engage in the behavior based on previous experiences or possible obstacles. Ajzen (2002) argues that people will have a greater intention or motivation to engage in objective behavior if they evaluate it positively (attitude).

According to Ajzen's model, environmentalist attitudes are composed of beliefs, emotions and intentions that positively influence the intention to adopt environmentalist behavior. At the level of results, these attitudes modulate support for public policies (Swim et al., 2009), the perception and self-efficacy (Hidalgo & Pisano, 2010), coping strategies and the intention to mitigate CC (Barrera-Hernández et al., 2021).

Climate Change Attitude Survey (CCAS)

Christensen and Knezek (2015) developed the Climate Change Attitude Survey (CCAS) based on a comprehensive review of the literature on attitudes toward CC. The survey covers 15 items and is structured around two main dimensions: *beliefs and behavioral intention*. A total of 1,576 individuals in the United States participated in the original study. An exploratory factor analysis revealed a two-dimensional structure accounting for 47.17 % of total variance. The presence of these two dimensions on the scale was confirmed through multidimensional scaling and hierarchical cluster analysis. The Cronbach's alpha internal consistency coefficients were suitable for both dimensions: beliefs ($\alpha = .87$) and behavioral intention ($\alpha = .70$).

This scale, based on Ajzen's (1991) Planned Action Theory, offers significant potential for adaptation and psychometric validation in the Latin American context to measure attitudes toward CC. Thus, its adaptation could lay a solid foundation for future regional research in this area.

This Study

As mentioned above, there are significant theoretical and methodological gaps in the Latin American literature when it comes to the psycho-social dimensions of CC (Forero et al., 2014; Medina-Arboleda, 2022; Sandoval-Díaz et al., 2021; Sapiains & Ugarte, 2017b). Though there has been a certain amount of empirical progress recently, developing psychometric instruments specifically adapted to the regional reality is essential. This will allow attitudes and behavior toward CC to be measured accurately. In this context, *measurement invariance* analysis is essential to ensuring that an instrument measures attitudes toward CC in different groups, such as men and women, in an equivalent way (Hair et al., 2010). Measurement invariance is evaluated across several levels to ensure that the observed differences between groups reflect real variations in attitudes and not measurement biases.

Several studies have suggested that women tend to be more concerned and have a higher perception of climate risk (Leiserowitz et al., 2013; McCright & Dunlap, 2011; Sapiains et al., 2024). However, the results on gender differences are mixed, highlighting the importance of applying measurement invariance to ensure that the differences detected reflect real variations and that they are not the product of the instrument's limitations.

The general objective of this work is to analyze the psychometric properties of the Climate Change Attitude Survey (CCAS) in the Chilean population. Its specific objectives are: a) to evaluate the validity of the CCAS's content through expert review, b) to analyze the descriptive statistics of the items and their discrimination indexes, c) to confirm the internal factorial structure of the scale through a confirmatory factor analysis (CFA), d) to perform a measurement invariance analysis to verify the scale's equivalence between men and women, e) to evaluate the convergent and discriminant validity and f) to estimate the scale's reliability.

Method

This study falls within the scope of instrumental or psychometric design (Ato et al., 2013) and its main objective is to analyze the psychometric properties of the CCAS scale in a sample of the Chilean population.

Participants

Non-probabilistic availability sampling was used and 800 Chilean adults participated, of which 54.1 % were women. The participants' age ranged between 18 and 71 years, with an average of 26.44 years and a standard deviation of 9.78. In terms of education, 1.4 % (11 people) declared having primary education, 65.9 % (527 people) declared having secondary education and 32.8 % (262 people) declared having higher education.

Regarding economic income, 52.5 % (420 people) declared having an income equal to or less than the Chilean minimum wage,¹ 18.9 % (151 people) declared having an income equal to or less than two minimum wages and 28.6 % (229) declared having an income equal to or greater than three minimum wages.

Instruments

Climate Change Attitude Survey (Christensen & Knezek, 2015). The survey is self-administered and has 15 items, with a five-point Likert response format that varies from (1) *totally disagree* to (5) *totally agree*. It is divided into two main dimensions:

- *Beliefs*: The first nine items evaluate participants' beliefs regarding CC (e.g., "I think our climate is changing").
- *Behavioral intent*: The remaining six items explore participants' intention to act on CC (e.g., "We can't do anything to stop global climate change").

Procedures

The guidelines established by the International Test Commission (2017) were followed to ensure the quality and validity of the measurements in this study. In the process of adapting the survey from English to Spanish, this work's authors initially participated in the translation's review and adjustment. A professional translator was subsequently engaged to ensure a precise and culturally appropriate semantic adaptation in accordance with the recommended functional equivalence. No significant changes were made to the linguistic adjustment, ensuring that the items retained their original meaning in the new idiomatic and cultural context.

The content was then reviewed with the help of expert judges, evaluated the survey items according to four fundamental criteria (Escobar-Pérez & Cuervo-Martínez, 2008):

- *Sufficiency*: The items must suffice to adequately measure the dimensions they represent.
- *Clarity*: The items must be easily understandable, both in their grammatical structure as well as their meaning.
- *Consistency*: The items must be logically related to the dimensions one aims to measure.
- *Relevance*: The items must be essential and, therefore, included in the survey.
- Each of these criteria was evaluated on a four-level scale: i) *non-compliant*, ii) *low level*, iii) *moderate* and iv) *high level*. In addition, qualitative observations were added to enrich the items' evaluation, following the recommendations of Cassepp-Borges et al. (2010).

For this evaluation process, 10 expert judges with postgraduate training and at least five years of teaching and research experience in the socio-environmental field collaborated. Nine of these judges were men and one was a woman. Seven of them had PhDs or were candidates for one, while the remaining three had master's degrees. It is crucial to note that these judges were not part of the research team and that they participated in the study voluntarily and free of charge.

¹ As of March, 1, in 2020, the year this study was carried out, the gross minimum wage was CLP 318,000, equivalent to USD 476 (Law No. 21,112).

Table 1
Characteristics of the judges evaluating the Survey contents

Judge	Discipline	Institution	Country
1	PhD in sociology	Universidad Nacional de Rosario	Argentina
2	MA in sociology	Universidad Andrés Bello	Chile
3	PhD in humanities	Universidad Bío-Bío	Chile
4	PhD in ecology and evolutionary biology	Universidad Bío-Bío	Chile
5	PhD in geography	Universidad Bío-Bío	Chile
6	PhD in psychology	Universidad Autónoma de Chile	Chile
7	MA in psychology	Universidad de Atacama	Chile
8	PhD in biology	University of Concepción	Chile
9	MSc. in environmental engineering	WSP Ambiental	Chile
10	PhD (c) in Geography	Pontificia Universidad Católica	Chile

Based on the criteria and previous evaluations, a pilot study of the adapted survey was implemented with a sample of 30 Chilean university students. The purpose of this pilot was to evaluate the survey's applicability and viability. As a result, adjustments were made to the instructions, the application format and the estimated time to complete the survey, thus reaching its final version.

This final version of the survey was implemented between August and October 2020, with an average duration of 20 minutes per participant. The data was collected using Google Forms, managed by previously trained university students. Due to mobility restrictions imposed by the COVID-19 pandemic, participants were recruited through digital social networks. They gave their consent to participate in the study by virtually signing an informed consent form and received no compensation for doing so.

Ethical Considerations

This study is part of the research project FOVI/ANID 230212 and was approved by the Universidad del Bio Bio Ethics Committee. The ethical principles set out in the Helsinki Declaration were rigorously followed to ensure the participants' confidentiality and privacy. Prior to participating, individuals were informed of the objectives, procedures, potential risks and benefits associated with the study. All necessary precautions were taken to protect participants' well-being and to ensure that the study meets the relevant ethical standards.

Data Analysis

Content Validity. This was analyzed using Randolph's (2005) marginal-free multirater and calculated using the Gwet (2010) variation formula and an online Kappa calculator (Randolph, 2008). The coefficient values vary from 0 to 1 and are interpreted according to the following agreement force ranges: (a) .00 = poor, (b) .10 – .20 = slight, (c) .21 – .40 = fair, (d) .41 – .60 = moderate, (e) .61 – .80 = substantial, and (f) .81 – 1.0 = almost perfect (Landis & Koch, 1977).

Descriptive Statistics. Items were examined through the calculation of univariate descriptive statistics and discrimination indexes. Corrected item-total correlations and the Mardia multivariate index were used (Hair et al., 2010; Mardia, 1970; Tabachnick & Fidell, 2013).

Confirmatory Factor Analysis (CFA). The Weighted Least Squares Means and Variance Adjusted (WLSMV) method, recommended for ordinal variables (Brown, 2015), was used. The model's goodness of fit was assessed using several indexes: Chi-squared (χ^2), Comparative Fit Index (CFI > .95), Tucker-Lewis Index (TLI > .95), Root Mean Square Error of Approximation (RMSEA < .06) and Standardized Root Mean Squared Residual (SRMR < .08), following the guidelines of Hu and Bentler (1999). The analysis was carried out using R software and version 0.6-9 of the "lavaan" package (Rosseel et al., 2018).

Factorial Invariance of Measurement. Current literature on psychometric validation stresses the need to demonstrate that the measurement model is independent of the sample characteristics (Hair et al., 2010). Findings are mixed when it comes to the gender variable's influence on attitudes toward CC (Beiser-McGrath & Huber, 2018; Zelezny et al., 2002). A progressive approach was adopted to evaluate invariance, which began with configural invariance and followed by metric, force and, lastly, strict

invariance using multigroup confirmatory factor analysis (Byrne, 2008; Chen, 2007). The differences between models were evaluated using the variations in the CFI (Δ CFI) and RMSEA (Δ RMSEA) indexes. Invariance is considered strong when Δ CFI ≤ 0 and Δ RMSEA ≤ 0.015 (Cheung & Rensvold, 2002).

Convergent and discriminant validity. For convergent validity, standardized factor loadings are expected to be significant and ≥ 0.50 (Bagozzi et al., 1991; Hair et al., 2010). Regarding discriminant validity, it must be verified that the square root of the extracted variance measurement (\sqrt VME) is higher than the square of the correlations between dimensions (Fornell & Larcker, 1981).

Reliability. Reliability was evaluated using the ordinal alpha coefficient, appropriate for polychoric matrices (Domínguez-Lara, 2018), and the composite reliability (CR) coefficient. Ordinal alpha and CR values of over .70 are considered to indicate adequate reliability (Gadernann et al., 2012).

Results

Interjudge Content Validity

Three types of agreement analysis between judges were carried out to evaluate the content validity. These analyses focused on: a) the dimensions of the evaluation scale, b) the agreement between different pairs of evaluating judges and c) the evaluation criteria used in the study.

First, it was observed that the two dimensions evaluated showed Kappa agreement coefficients ranging between substantial and almost perfect, as detailed in Table 2.

Table 2

Agreement coefficient for each scale dimension of the scale

Dimension	Free-marginal-Kappa coefficient	95 % CI	Force of agreement ¹
Beliefs on climate change	.82	.75 - .89	Almost perfect
Behavioral intention	.78	.69 - .88	Substantial

Note. Force of agreement, interpretation according to Landis and Koch (1977).

Second, the Kappa agreement between pairs of expert evaluators was almost perfect in both the dimension related to beliefs as well as the behavioral intention dimension (see details in Appendix A).

Third, the results showed agreement levels that vary according to the different evaluation criteria: agreement was fair in the sufficiency criterion, substantial in consistency and almost perfect in the relevance and clarity criteria. These data are detailed in Table 3.

Table 3

Kappa coefficient in the four areas evaluated

Areas	Free-marginal-Kappa coefficient	95 % CI	Force of agreement
Sufficiency	.26	-.51 - .31	Fair
Consistency	.76	.67 - .85	Substantial
Relevance	.91	.85 - .98	Almost perfect
Clarity	.83	.75 - .91	Almost perfect

Lastly, the expert panel's observations in the qualitative area led to the decision to preserve all items in the instrument. In addition, satisfaction was expressed regarding its administration format and length.

Descriptive Statistics

First, it should be noted that no data were found to be missing in the data set reviewed. Second, 11 of the 15 items evaluated surpassed the threshold of ± 2 in the values of asymmetry and univariate kurtosis. This observation led to the potential elimination of items 5 and 15, which showed asymmetry values greater than ± 3 , in line with the criteria of Tabachnick and Fidell (2013). In relation to the

multivariate normality analysis, the symmetry coefficient remained within acceptable ranges, but the kurtosis coefficient did not comply with the guidelines established by Mardia (1970). This indicates the need to use robust estimators and extraction methods for the factor analysis, as per the recommendations of Lloret-Segura et al. (2014). Lastly, all item-total correlations were positive, as shown in Table 4.

Table 4

Exploratory analysis corresponding to the survey's items (n = 800)

Subscale/item	<i>M(DE)</i>	ASY	K	<i>r</i> _{it}
1. I believe our climate is changing.	4.53(.86)	-2.59	7.56	.57
2. I am concerned about global climate change.	4.39(.79)	-1.82	4.69	.68
3. I believe there is evidence of global climate change.	4.50(.76)	-2.29	7.08	.69
4. Global climate change will impact our environment in the next 10 years.	4.47(.78)	-1.94	4.91	.60
5. Global climate change will impact future generations.	4.69(.71)	-3.33	13.0	.59
6. The actions of individuals can make a positive difference in global climate change.	4.33(.82)	-1.59	3.29	.55
7. Human activities cause global climate change.	4.30(.82)	-1.46	2.78	.58
8. Climate change has a negative effect on our lives.	4.39(.77)	-1.60	3.57	.62
9. We cannot do anything to stop global climate change.	4.17(.96)	-1.30	1.52	.40
10. I can do my part to make the world a better place for future generations.	4.34(.81)	-1.71	4.07	.55
11. Knowing about environmental problems and issues is important to me.	4.26(.75)	-1.20	2.65	.54
12. I think most of the concerns about environmental problems have been exaggerated.	4.17(.96)	-1.37	1.81	.47
13. Things I do have no effect on the quality of the environment.	3.78(1.04)	-.75	.07	.36
14. It is a waste of time to work to solve environmental problems.	4.53(.78)	-2.34	6.69	.46
15. There is not much I can do that will help solve environmental problems.	3.84(1.03)	-3.63	-.42	.44

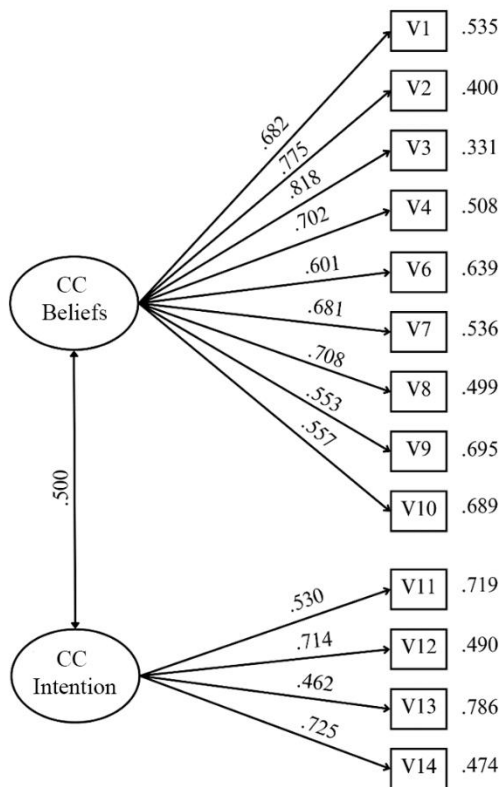
Note. Mardia K: 131.86, $p = .00$. Mardia ASY: 75.38, $p = 1.00$. ASY: asymmetry coefficient; K: kurtosis coefficient; rit: total item-scale correlations; Mardia K and As: Kurtosis coefficient and multivariate asymmetry.

Confirmatory Factor Analysis

A CFA was initially carried out with the 15 original items, with an insufficient fit obtained according to the criteria of Hair et al. (2010). The results were: $\chi^2(89) = 728.100$, $p = .000$; RMSEA = .095 (IC of 95 % = .088 – .101); TLI = .839; CFI = .864; and SRMR = .079. On the other hand, the internal consistency coefficients (α) were: $\alpha = .823$ for the belief subscale and $\alpha = .711$ for the intention subscale, suggesting an acceptable internal consistency for beliefs, but marginal for intention.

Items 5 and 15 were eliminated after being identified as problematic in the previous phase. The new CFA showed a better fit with the two-factor model: $\chi^2(78) = 2719.209$, $p = .000$; RMSEA = .046 (IC of 95 % = .039 – .053); TLI = .946; CFI = .955; and SRMR = .043 (Figure 1).

Figure 1
CFA results for the CCAS scale ($n = 800$)



A measurement invariance analysis was carried out to progressively evaluate configural invariance (M1), thresholds (M2) and factor loadings (M3), according to Wu and Estabrook (2016). Due to the ordinal nature of the variables, the robust estimator WLSMV estimator was used (Brown, 2015). The results of the unrestricted base model for both groups (M1) are presented in Table 5, showing excellent fit rates (CFI = .947, RMSEA = .062, SRMR = .046). This model served as a reference for the M2 and M3 models. In the M2 model, which examines threshold invariance, good fit rates (CFI = .945, RMSEA = .060, SRMR = .056) and minimal changes compared to M1 were observed, supporting threshold invariance. The M3 model, which evaluated the invariance of factor loadings, also displayed good fit rates (CFI = .942, RMSEA = .060, SRMR = .057) with minimal differences compared to M1, indicating the invariance of factor loadings. To assess structural invariance, an additional model (M4) was established with equal factor variances between groups. The values obtained (CFI = .934, RMSEA = .061, SRMR = .062) did not exceed the recommended minimum differences, suggesting that structural invariance is complied with. In sum, invariance analyses revealed good fits with the models evaluated, supporting the measurement invariance at the configural, threshold and factor loading levels.

Table 5
Factorial invariance analysis by sex for attitudes

Models	χ^2 (df)	$\Delta\chi^2$	Δdf	p	SRMR	CFI	RMSEA	ΔCFI^*	$\Delta RMSEA^*$
Women	148,622 (64)	-	-	.000	.050	.929	.055	-	-
Men	122,200 (64)	-	-	.000	.049	.944	.051	-	-
M1	367.04 (128)	-	-	-	.046	.947	.062	-	-
M2	396.25 (139)	13.789	11	.02449	.056	.945	.060	-.002	-.002
M3	419.30 (150)	23.495	11	.01504	.057	.942	.060	-.003	0
M4	488.04 (163)	21.544	13	.00628	.062	.934	.061	-.008	0.001

Note: M1: Configurational; M2: Metric; M3: Strong; M4: Strict.

Evidence of Discriminant, Convergent Validity and Internal Consistency

Regarding convergent validity, the results presented in Table 6 indicate that all items showed statistically significant factor loadings of over .5. However, it is important to note that the AVE (Average Variance Extracted) value was lower than the recommended minimum in both factors. Despite this, the square roots of the extracted variance measurement (\sqrt{VME}) were shown to be higher than the correlations between dimensions.

In addition, the composite reliability (CR) coefficients and ordinal alpha coefficient registered slightly better values compared to the original 15-item structure ($\alpha = .823$ for beliefs and $\alpha = .711$ for behavioral intention), which reinforces the internal consistency of the evaluated dimensions (see Table 6).

Table 6
Validity and reliability indices corresponding to the dimensions of attitudes toward climate change

	M	DT	AVE	\sqrt{AVE}	α	CR
1. Behavioral intention	4.08	.70	.39	.62	.75	.75
2. Beliefs about CC	4.43	.56	.44	.67	.88	.89

Note: Correlation between factors 1 and 2 ($r = .486$; $R^2 = 0.236$).

Discussion

The initial results show that the Climate Change Attitude Survey applied to Chilean adults has a bidimensional factor structure with 13 items aligned with the original version. Items 5 and 15 were excluded due to their poor fit in the structural model (SEM), problems with multivariate normality and low internal consistency compared to the final adjusted version. These findings should be interpreted with caution, since the removal of these items could modify the instrument's original theoretical conceptualization (Carretero-Dios & Pérez, 2005). Nevertheless, the results continue to back the theoretical validity of attitudes, particularly in the dimensions of beliefs and behavioral intention, according to Ajzen and Fishbein's (1977) theory and other research (Gifford, 2014; IPCC, 2018; Kollmuss & Agyeman, 2002; Maiteny, 2002).

The CFA showed a good fit for the 13-item model, which reinforces the validity of the survey's new internal structure. Though a specific adjustment was made in item 11, which was moved from the "Intention" dimension to "Beliefs", it is important to continue evaluating whether this change effectively improves the model's conceptual coherence, considering that the item addresses cognitive aspects of environmental knowledge.

Regarding the invariance analysis, the results indicated that the survey structure and factor loadings were consistent between men and women. This suggests that the instrument measures both genders equivalently, in line with the international literature (Beiser-McGrath & Huber, 2018), which supports the survey's validity in different subgroups.

In addition, evidence of convergent and discriminant validity was found. Though the average extracted variance (AVE) was slightly lower than the recommended threshold, this finding is offset by the fact that the square roots of AVE exceeded the correlations between factors, reinforcing the instrument's discriminant validity.

Lastly, the survey showed adequate reliability in both dimensions, with better values than the original 15-item version. This confirms that the survey is a useful, accurate and reliable tool for measuring attitudes toward CC.

This study brings up several aspects to be considered in new research. The content validity review suggests that while the "sufficiency" category registered an acceptable value, it would be advisable to review the number and relevance of items in each dimension more thoroughly. This becomes especially important after the removal of items 5 and 15, as it may have affected the full coverage of the theoretical constructs that the survey measures. This aspect should be considered in subsequent studies to ensure that the survey appropriately captures all relevant facets of attitudes toward CC (Carretero-Dios & Pérez, 2005).

From a methodological perspective, while the structure obtained is similar to that of the original model (Christensen & Knezek, 2015), it is crucial to stress that different statistical decisions were made. In the original research, the principal component method was used to identify "the number and composition of components needed to summarize the scores observed in a large set of variables" (Lloret-Segura et al., 2014, p. 1,153). In contrast, this study used Factor Analysis, which "identifies the number and composition of the common factors needed to explain the shared variance of the set of items analyzed" (Lloret-Segura et al., 2014, p. 1,152). Furthermore, instead of using Cronbach's alpha, this study used composite reliability coefficients and ordinal alpha, more appropriate for the analysis of ordinal Likert-type variables (Domínguez-Lara, 2018).

Regarding the study's limitations, it is important to highlight the possible lack of sample representativeness, as participants' access was virtual due to the restrictions imposed by the pandemic. This may have reduced the sample's heterogeneity. Future research should consider the implementation of stratified probabilistic sampling, which would allow improved representation of the population regarding CC, including variability in relevant aspects such as territoriality, differentiating between urban and rural areas (Peña-Garay & Sandoval-Díaz, 2024), in addition to sociodemographic factors such as age and having children (Sapiains et al., 2024). Another aspect to bear in mind is that the survey was applied in a single moment, which limits evaluation of the instrument's temporal reliability and obtaining information on the construct's stability over time. Lastly, the incorporation of greater evidence of validity is recommended, such as concurrent or predictive validity, comparing the scores on the scale with other variables related to attitudes toward CC. This would help confirm that the instrument effectively measures what it intends to and establish its relationship with other relevant dimensions, such as awareness, risk perception and environmentalist behavior.

In sum, this study's results offer a psychometric instrument that has been adapted and validated in Spanish to evaluate attitudes toward CC among Chilean adults, contributing to narrowing the psychometric gap in Latin American research (Forero et al., 2014; Reveco-Quiroz et al., 2022). The CCAS scale, in its 13-item version, has proven to be robust with adequate evidence of content validity, internal structure and factor invariance by gender, which ensures its applicability in different population subgroups. It also has adequate reliability levels, making it a useful tool for future studies in the field of behavioral sciences. In particular, it is relevant for evaluating different psychosocial dimensions of CC in the Latin American context (Clayton, 2019, 2024; Corral-Verdugo, 2021; Medina-Arboleda, 2022; Vidal Cobo et al., 2021), as well as examining CC mitigation and adaptation strategies (Barrera-Hernández et al., 2021; Sandoval-Díaz et al., 2023; Sapiains & Ugarte, 2017; Sierra-Barón & Millán-Otero, 2024). Despite this progress, there is a need to continue with studies that delve into temporal stability and validation with other CC-related variables to strengthen its applicability in future research.

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Appendix A

Table A1

Agreement coefficient by dimension between pairs of judges

Judges	Dimension	
	<i>Beliefs on climate change</i>	<i>Behavioral intention</i>
1-2*	0.86	1.00
1-3	0.76	0.86
1-4	0.81	1.00
1-5	0.76	0.93
1-6	0.71	0.58
1-7	0.76	0.86
1-8	0.57	0.72
1-9	0.86	1.00
1-10	0.81	0.93
2-3	0.90	0.86
2-4	0.95	1.00
2-5	0.90	0.93
2-6	0.86	0.58
2-7	0.90	0.86
2-8	0.71	0.72
2-9	1.00	1.00
2-10	0.95	0.93
3-4	0.86	0.86
3-5	0.81	0.79
3-6	0.76	0.44
3-7	0.81	0.72
3-8	0.67	0.58
3-9	0.90	0.86
3-10	0.86	0.79
4-5	0.86	0.93
4-6	0.81	0.58
4-7	0.86	0.86
4-8	0.67	0.72
4-9	0.95	1.00
4-10	0.90	0.93
5-6	0.76	0.51
5-7	0.81	0.86
5-8	0.71	0.72
5-9	0.90	0.93
5-10	0.90	0.93
6-7	0.76	0.44
6-8	0.67	0.58
6-9	0.86	0.58
6-10	0.81	0.51
7-8	0.62	0.72
7-9	0.90	0.86
7-10	0.86	0.93
8-9	0.71	0.72
8-10	0.71	0.79
9-10	0.95	0.93

Note: *Number corresponding to each judge (Judge 1, Judge 2, Judge 3, Judge 4, Judge 5, judge 6, judge 7, judge 8, judge 9, judge 10).