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How does private adaptation motivation to climate change vary across cultures? Evidence from a meta-analysis

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ABSTRACT

Natural hazards, exacerbated by climate change, increasingly affect societies worldwide. The accelerating risks entail that private adaptation complement more traditional public climate change adaptation measures. Culture plays an important role in framing how individuals experience hazards and behave toward them. Yet, empirical research explicitly measuring whether and how climate change adaptation varies across cultures is lacking. To address this gap, we collect meta-analytic data on factors motivating individual flooding adaptation from 25 countries and more than 50 publications. Employing Hofstede's Cultural Rankings as a metric of national culture, we model the effect of culture on adaptation motivation of individual households using meta-regression analysis. We find a number of statistically significant relationships between culture and factors motivating private climate change adaptation. Hence, cultural context is vital to consider when designing and implementing climate change adaptation policies, simulating the uptake of individual hazard prevention measures, or integrating private adaptation in assessing costs of climate change in integrated assessment models. These findings are among the first to provide empirical evidence on the interaction effects between culture and private climate change adaptation motivation.

1. Introduction

Adaptation to climate change is at the forefront of both political and academic environmental discourse [1,2]. Research has shown that public adaptation measures on their own, are insufficient to address the projected impacts of climate change [3–5]. Coordinated adaptation across scales, where private anticipatory actions, including individual household behavior, complement public adaptation measures, offers the best prospect for confronting adverse climate change impacts [3,4,6].

To date, much of the empirical work on private climate change adaption has taken place in Europe and North America [80]. This is problematic as the nations' least responsible for the global emissions, primarily located in the Global South, will be disproportionately impacted by climate change [8]. The numerous appeals for more cross cultural research, arise from the growing understanding that the success of adaptation strategies and policies depends on taking into account social, political, cultural, and demographic factors [9]. Individual perceptions of climate-induced risks, decisions whether to adapt, and what actions to take are mediated by culture [10]. Recent cross-national

studies on climate change perception and public adaptation explicitly highlight the need to consider cultural and geographical differences when looking at individual perception and adaptation to climate change across countries [11–13]. Yet, these differences have been insufficiently addressed when looking at private adaptation to the impacts of climate change.

Among climate change impacts, floods are among the most devastating and costly [14,15]. Public flood adaptation measures such as levees or governmental refund programs that have been successful in the past, face limits in the new climate-altered reality [16,81]. Similar to the broader field of climate change adaptation, there is strong agreement that culture influences natural flood risk perception and individual adaptation behavior [18,19]. However, with a few exceptions, cross-national empirical research has been limited; both the number of publications and in the number of countries included in the surveys [20–23]. Similar responses in individual adaptation to disasters are found on a case by case basis [24], however a deficit of research in much of the Global South and cross-nationally, means that generalizations across countries and cultures fundamentally lack empirical support. The

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vast majority of flood surveys neglect cultural or national differences when examining individual adaptation behavior to floods.

Therefore, the question as to whether there are patterns in how various aspects of culture affect individual climate adaptation behavior, remains open. Two recent meta-analysis provide an ample overview of the empirical literature on hazard adaptation motivation. Van Valkengoed and Steg [25] provide insights on factors behind climate adaptation motivation toward *all* natural hazards. The meta analysis by Bamberg et al. [26] focuses solely on flooding, exclusively through the lens of *Protection Motivation Theory* (PMT). However, neither review reveals how individual adaptation behavior to climate change differs cross-nationally or across cultures. Individual risk perceptions and behavior may vary by type of hazard an individual face, potentially obscuring whether the observed variance in the review by Van Valkengoed and Steg [25] is due to the hazard differences or the study location [18,27,28]; p.28). Bamberg et al. [26] provides a comprehensive review on flooding, but focuses exclusively on five PMT factors influencing adaptation and omits factors outside this scope. Moreover, the review utilizes a limited number of independent surveys, diminishing the suitability to explore cross-cultural differences. Importantly, both meta-analyses use a random effects model, indicating that a distribution of effect sizes exists for each of the factors motivating individual climate change adaption behavior. Furthermore, both meta-analyses state that some of the variance in the choice model would be explained through the further inclusion of descriptive and social norms. These norms describe what people perceive others as doing, as well as the 'unwritten' behavioral rules and values of a society. Direct study of these norms requires place-specific research as both norms strongly inform and are influenced by culture [19,29].

Culture can yield a better understanding of individual behavior through contextualizing the norms and values that are intertwined with it. The concept has received considerable attention through out the years, both in academic discussions: i.e. [30] as well as in literature: i.e. [31]. While there is not *one* overarching definition, in this article we define culture as the following [32]; p.6): "Culture is the collective programming of the human mind that distinguishes the members of one human group from those of another. Culture in this sense is a system of collectively held values." This definition emphasizes the role that a collective construct such as culture can play in influencing individual actions. While there are many boundaries one can draw to define different collectives, for the purposes of this article we select the national level. Hence, we focus on the associations between national culture and individual behavior.

Methods to analyze culture often require ethnographic and observational research and yield qualitative data that is more frequently utilized by anthropologists and sociologists, rather than climate and disaster researchers [10,33]. There are however several approaches that quantitatively characterize different national cultural dimensions. A few in particular stand out: Hofstede's Cultural Dimensions [34], the "GLOBE Project" [35] and several other rankings created from, or validated by, the Worlds Value Survey (WVS) [36]. All utilize empirical data collected from extensive cross-national surveys allowing for comparisons across a broad scope of countries. We selected Hofstede's Rankings for its suggested superior ability to predict behavioral frequencies when compared to GLOBE [29] and for the greater data availability for countries in which flood surveys were conducted when compared to the WVS′ rankings.

The aim of this article is to quantitatively and systematically examine if there are observable patterns in how factors motivating individual climate change adaptation behavior relate to culture. To test this we review 53 independent studies reporting surveys on households' adaptation actions and collect bi-variate associations of factors motivating individual adaptation, taking flooding as an example. Based on the country where the survey data was conducted, we plot the collected bi-variate associations against Hofstede's national cultural rankings. The analysis is exploratory in nature, and aims at testing the general

hypothesis' that certain factors motivating adaptation will be moderated by cultural dimensions. The innovative contribution of this paper to the literature is two-fold. First, to the best of our knowledge, for the first time the interaction effects between culture and factors motivating private climate change adaption are measured with a sufficiently large country sample - more than 10 countries [32]; p.30) - to distinguish cultural differences. Second, our extensive meta-analytic review affords statistical support for a previously contradicted difference in the effect size of risk perception toward intended vs. undergone adaptation. This distinction between actual and intended adaptation to climate-induced risks is important in understanding the feedback effects between individual behavior and perceptions.

The remainder of the paper is organized as follows: Section 2 outlines the methods used to collect and transform the data. In Section 3 we test for a difference in factors motivating intended vs. undergone adaptation to floods, sample size permitting. Following this, we present the meta-regression analysis to measure the interaction effects between factors motivating private adaptation and Hofstede's six cultural rankings. Section 4 discusses the broader implications of this research and concludes.

2. Methods

2.1. Literature search strategy

To obtain data on individual behavior and flooding in a multinational context, we conducted a thorough literature search in 2019. We focused on households' surveys reporting individual flood damage mitigation and adaptation actions against flooding published in English as peer reviewed articles. Six different keyword combinations of "Individual", "Household", "Flood", "Adaptation", "Protection", "Motivation", and "Survey" were searched on SCOPUS and Web of Science (WoS), and Google Scholar in2019.[1] The search returned approximately 100,000 results on Google Scholar, and, in total, just over 200 for WoS and SCOPUS. The first 100 results for each search were reviewed on Google Scholar and all results were reviewed on SCOPUS and WoS.

If the title or abstract mentioned a survey, a sample size, empirical data, or factors motivating adaptation, the article was screened to determine if it contained quantitative, bi-variate associations or *effect sizes* (ES) of factors motivating private flooding adaptation. ES are a way to measure the strength of an association and once standardized, allow for cross-study comparisons of the effects that different factors have on adaptation motivation. We collected several different means of reporting ES: *Pearson's r, Spearman's rho, Kendall's Tau,* other test statistics: *chi squared (df = 1), odds ratios* and linear and logistic *standardized regression coefficients* (β). Only articles reporting ES in any of these formats were included in our evidence base. We removed duplicates and excluded or combined articles reporting data from the same survey before merging all search results into a single dataset.

Further, if a survey measured individual adaptation toward multiple hazards such as a hurricane and a flood, we included it as long as adaptation to any type of flood adaptation was explicitly surveyed (flash flood, coastal flooding, dam/levee over-topping, etc.). The reported individual adaptive actions towards flooding varied greatly across surveys and locations and included: insurance purchase, emergency preparedness measures, information acquisition, alterations to own home, and many other actions. Factors motivating individual adaptation were additionally manifold. Meta-regression analysis requires that a factor is reported sufficiently frequent to be eligible for inclusion. If 10 or more surveys reported a factor of interest, we included it in our analysis.

Ultimately the aforementioned criteria yielded selected seven factors that were reported sufficiently frequent. Two factors: 'Risk Perception' and 'Self Efficacy' were asked often enough that we were able to distinguish between their effect in motivating intended, vs. undergone adaptation. Undergone adaptation is measured when the survey asks about action that has already taken place or is concurrent; whereas intended adaptation is an action the individual aspires to accomplish. Additionally, for Risk Perception, whenever possible we distinguished between its two components by recording whether it was the *probability* of the flood or the expected *damage* of the flood that motivated adaptation. These sub categories led to a total of 13 collected factors that motivate individual flooding adaptation (Table 1).

Focusing on this selection of 13 factors, we narrowed down our sample of surveys on private adaptation to climate driven flooding to a total of 72 reported surveys. We excluded three studies where the *only* adaptation measured was relocation, out-migration, or evacuation as these retreat options are a fundamentally different type of adaptation compared to the accommodating measures that dominate the majority of measured private adaptation to flood risks [37]. Furthermore another study was excluded since it grouped the results from two different countries, while our intention is to compare the differences between countries. Finally, surveys were further excluded if they did not report standardized ES, or the ES of a factor's *direct* impact on motivating flooding adaptation. To maximize the number of data points, we used the supplemental flooding adaptation motivation data provided by Ref. [25] that they received by contacted authors for data not available in the original publications.

Following these search criteria, we compiled a dataset based on 53 independent publications (56 surveys) from 25 different countries, and the total number of respondents $N = 38,891$. If a study reported multiple ES (e.g. several ES of risk perception motivating different adaptive actions), or two studies used the same survey population to measure different types of adaptation the results were combined so as to maintain

Table 1

The 13 factors motivating private adaptation to floods used in our meta-analysis of reported effect sizes worldwide. 'Social Influence' and 'Institutional Faith' are comprised of multiple reported effect sizes to achieve a sufficiently large sample of observations (≥ 10).

Factors Motivating Adaptation	Explanation
1. Risk Perception (RP)	All reported ES for Risk Perception are included here. Combines ES for intended and undergone adaptation and ES probability and damage
2. RP: Undergone Adaptation	Combines both the ES for probability and damage given that adaptation has already occurred
3. RP: Intended Adaptation	Combines both the ES for probability and damage given a reported intention to pursue adaptation
4. RP: Probability of flood	Combines the ES of individual assessment of probability of flooding in both intended and undergone adaptation
5. RP: Damage due to flood	Combines the ES of individual assessment of damage from flooding in both intended and undergone adaptation
6. (Prior) Flood Experience	ES were collected for any mention of flood experience
7. Age	ES were not collected if the ES of age was reported categorically
8. Gender (Female)	ES were collected or transformed for the Female gender
9. Self Efficacy (SE)	All reported ES for Self Efficacy are included here. Combines ES for intended and undergone adaptation
10. SE: Undergone Adaptation	ES indicates relationship between Self Efficacy and undergone adaptation
11. SE: Intended Adaptation	ES indicates relationship between Self Efficacy and indented adaptation
12. Social Influence	'Information received', 'expectations', 'social support', and 'perceived stigma(s)' from family, friends, neighbors, and/or the local community)
13. Institutional Faith	'Information' provided by a governmental body/the media, and/or the individual's 'trust' in the government, and/or 'adaptive actions' undertaken by a governmental body

the independence of each recorded ES; a critical component in a meta-analysis [38]. However, if within a study two independent factors were reported with different N's - for example for 'Risk Perception' and 'Prior Flood Experience' - they were recorded separately with their respective N's to ensure precise weighting, as discussed in detail below, but were not double counted.

2.2. Cultural rankings

Culture itself is not static. Rather it is shaped by a dynamic set of social relations and complex practices that influence individual behavior and inform decision making processes. These complexities make culture a "messy" [39], but crucial concept to consider when looking at individual behavior surrounding natural hazards. Hofstede's ranking are suggested to be superior in predicting behavioral frequencies when compared with other cultural measurements [29]. We therefore select it as the culture metric for this study. The cultural ranking scores for each of Hofstede's cultural dimensions are based on the empirical data collected from internationally comparable surveys [32]. For the purpose of our meta-analysis we rely on the data from the Hofstede's web-site [34]. Namely, we use six cultural dimensions in our analysis:

1. **Individualism** vs. Collectivism: In Individualistic societies, people are more autonomous and the ties between members of the society are less rigid compared to Collectivist cultures. Individuals are primarily responsible for themselves and immediate family. In Collectivist societies, members are born into clearly defined groups, to which they belong, protect, and are protected by throughout their life.
2. **High Power Distance** vs. Low Power Distance: The "degree of acceptance" from less powerful members of society for an unequal power distribution and authoritarian decision-making vs. individual expectations to participate in decisions impacting them.
3. **High Uncertainty Avoidance** vs. Low Uncertainty Avoidance: The degree to which members of society are averse to unknown situations. Cultures that avoid uncertainty prefer a clear set of rules, laws and regulations that offer structure and an opportunity to plan so that possible risks are minimized.
4. **Masculinity** vs. Femininity: A Masculine society has distinct, stereotypical gender roles, a strong focus on material success, individual achievements, strength and wealth. A feminine society has more loosely defined gender roles and members are typically more concerned with quality of life, nurturing for each other and for the environment. Feminine cultures resolve disagreements through negotiations rather than forcing solutions typical for the masculine ones.
5. **Long Term Orientation** vs. Short Term Orientation indicate the role of time for different cultures: Long Term Oriented societies prioritize future gains and value persistence, ability to adapt and long-term fulfillment. Shorter Term oriented values focus more on immediate and even past rewards such as tradition and preservation of face.
6. **Indulgence** vs. Restraint: Indulgence is a society's acceptance of activities that are hedonistic and cherish enjoyment. In more restrained cultures personal happiness and freedom are disapproved by social norms as these activities are seen as needing to be restrained.

Within each of these six dimensions, a country can score between 1 and 100, relative to other countries. A higher score indicates *more* of the core characteristic highlighted in bold above. For example, a country with a score of 75 for the Individualism vs. Collectivism category is more individualistic than a country with a score of 50. All of the cultural ranking scores were taken from Hofstede [34] in January, 2020 with two exceptions: Ethiopia did not have scores for two cultural dimensions: Long Term Orientation and Indulgence; and thus the study that took place in Ethiopia was excluded from the analysis in only these two

categories. Cambodia has no scores for any cultural dimension, however using a recent article [40] that discusses Hofstede's cultural dimensions in relation with Cambodia's ranked neighbors, we calculated coefficient estimates for each cultural dimension. See Appendix A for further explanation.

2.3. Bonferroni correction

In testing for associations across six cultural dimensions and 13 factors motivation adaptation there is the potential for 'type I' errors. For greater assurance that the our meta regression findings are not due to chance, we employ the Bonferroni correction. The usefulness in employing the Bonferroni method (Equation (1)) to limit the possibility of a 'type I' error is contested [41,42]. It is a very conservative method that sharply increases the likelihood of a 'type II' error, particularly in research with limited data, such as the current study. As a best practice we report both standard p-values and significant results after the Bonferroni correction in Table 2. Yet, given the limitations of the conservative Bonferroni method and its rare use in meta analytical reviews, our discussion is not limited to the two Bonferroni-significant relationships between ES of factors motivating adaptation and cultural dimensions. We test the impact of culture on *each* factor motivating adaptation, thus we likewise employ the Bonferroni adjustment per factor.

$$P(H_i \text{ passes} \mid H_0 \text{ is true}) = \frac{\alpha}{\nu} \tag{1}$$

In Equation (1), α is the desired significance level overall (0.05) and ν is the number of statistical test run for each hypothesis; in this case, six: the number of Hofstede's cultural dimensions. This leads to a Bonferroni corrected significant level of 0.008. The significant meta-regression coefficients for all of the ES of the factors influencing adaptation and cultural rankings are presented in Table 2.

2.4. Data processing: effect sizes, creditable intervals, and distinguishing between intended and undergone adaptation

Finally, to allow comparison between the collected ES of the 13 factors motivating individual adaptation with the six cultural dimensions, initially we needed to standardized them. First, we transformed all ES into Pearson's r, and then converted them using the variance-stabilizing Fisher's r to z transformation (please refer to Appendix B for equations) [38]. Second, once transformed, we apply the random effects model on the factors in the dataset, weighted by the inverse variance, within and between the surveys. A random effects model, as opposed to a fixed effect model reflects a belief that there is more than one "true" ES. Following Veroniki et al. [43]; we select Paule-Mandel's estimator for calculating the between study variance. The random-effects-weights for the individual and pooled values were calculated in R (3.6.1) using the "Metafor" package [44]. We applied the assigned weights (percentages) to each study, then multiplied by the number of studies that reported an ES for a given factor to have the appropriate random effect weights for each *individual* study. This permitted us to run analysis with the individual studies weighted by random effects (e.g. meta-regression analysis) and not simply consider the pooled effect size. Third, the sum of the weighted individual study values was used to cross-check the pooled random-effect-weighted means. Finally, the weighted z-transformed correlations were re-converted into the commonly used ES of Pearson's r for the analysis with culture and the reporting on meta-analytic findings. Fig. 1 illustrates the pooled random-effect-weighted of the seven main ES in Pearson's r.

Bayesian Credible Intervals provide a more conservative estimated range for each factor in comparison to frequentist confidence intervals [45]. Fig. 1 displays the mean ES and the Bayesian Credible Intervals for the seven principle factors affecting individual adaptation motivation. The ranges do not test if there is a statically significant effect (i.e. if zero

is captured in the interval), but rather where the averaged ES plausibly falls. We use uninformed priors when estimating the pooled distribution and do not differentiate between adaptation intention and action due to limited sample size.

3. Results and discussion

The results of this meta analysis are based on 53 independent studies reporting 56 surveys on households' adaptation actions across 25 countries, with the total number of N = 38,891 respondents. Fig. 1 presents the mean of the pooled ES for seven factors and their distribution. Much of the variation in individual adaptation actions measured, question phrasing and response, and time since the last flood all likely contribute to some of the variation in the ES estimation [38, 46]. Due to sample size restraints (with adaptation actions measured) and lack of reported information (with the number of years since the last flood) we could not control for any of the above mentioned suspected sources of variance. We hypothesize however, that a substantial part of the variance may originate from two factors: lack of differentiation between intended and undergone action or the variance could be influenced by cultural variations in the survey locations. These two sources of variance suggest the need to look beyond the aggregated values and focus on potential differences within each factor.

3.1. Intention vs. action

In our dataset, Risk Perception and Self Efficacy are the only factors motivating adaptation surveyed in sufficient frequency to differentiate between individual intention to adapt to flooding and the actual adaptation action pursued by households across the world.[2] One hypothesis is that individuals with high Risk Perception in the past could have already taken adaptation actions, and thus perceive present flood risks as lower [82]. Likewise, an individual's present Self Efficacy, could be based on the relative success of previously undergone adaptation. However, it is methodologically challenging to test these temporal feedbacks between Risk Perception, Self Efficacy and individual adaptation to floods from a one-time survey that only captures a snapshot of the interplay of these behavioral factors and adaptation action.

Previously, Bamberg et al. [26] used meta-analytic data collected from PMT surveys measuring intention and undergone adaptation to test the hypothesis on risk perception contingency on previous adaptation actions. Bamberg et al. [26] find that the effect of Risk Perception on undergone action is generally higher than the effect on intended adaptation. This finding contradicts the hypothesis of Bubeck et al. [82] that individual risk perception should diminish after one has taken a flood adaptation measure. The dataset behind our meta-analysis utilizes a larger sample of studies compared to Bamberg et al. [26]'s and goes beyond studies guided by PMT. Due to the non-normal distribution, sample size, and a desire to accurately communicate the size of effect, we again select a Bayesian method to examine the means of the ES of Risk Perception effect on intended versus undergone adaptation; this time with Bayes' Factor [48]. We calculate Bayes' Factor in R using the "Statsr" package [49] assuming Zellner-Siow Cauchy prior for the mean difference due to the non-normal expected distribution of the data.

We compare the mean ES of Risk Perception toward intended private adaptation with the mean ES of Risk Perception after households have already undertaken an adaptive action (Fig. 2). Our results reveal a greater effect of risk perception in motivating an individual's intent to adaptation, in comparison to explaining previously undergone adaptive action. The latter ES of Risk Perception has a clear peak at around 0.1 and spreads below zero. This indicates there are cases where households

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[2] We could not do the same with Flood Experience (the other factor with a relatively large N) due to a lack of studies that measured intended adaptation and reported on the ES of Flood Experience.

Table 2

Regression coefficient estimates of different factors motivating adaptation weighted by random effects. Here we list values only for those that have a statistically significant relationship with Hofstede's Cultural Rankings: (**I**): Individualism - Collectivism, (**II**): High - Low Power Distance, (**III**) High - Low Uncertainty Avoidance, (**IV**): Masculinity - Femininity, (**V**): Long - Short Term Orientation, (**VI**): Indulgence - Restraint. (N = number of surveys, n = number of respondents, c = number of countries, significant values after the Bonferroni corrected significance level (0.008) are underlined).

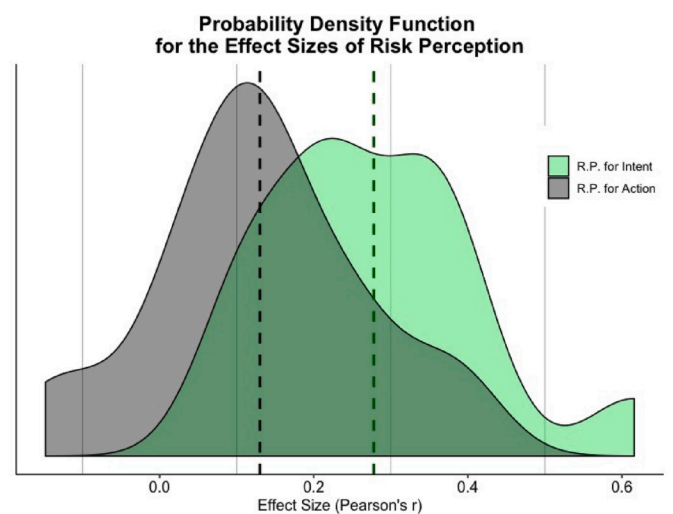|	Hofstede's Cultural Rankings:					
	I	II	III	IV	V	VI
1. Risk Perception (RP) (N = 41, n = 26,856, c = 16)						
2. RP: Undergone adapt (N = 30, n = 21,954, c = 13)						
3. RP: Intended adapt (N = 14, n = 5182, c = 7)						
4. RP: Probability (N = 15, n = 7082, c = 10)				−0.003*		0.007**
5. RP: Damage (N = 15, n = 5626, c = 11)					−0.006*	
6. Flood Experience (N = 27, n = 18,257, c = 16)	−0.005***	0.006**	−0.004*			
7. Age (N = 18, n = 14,294, c = 15)		0.002*				
8. Gender (Female) (N = 17, n = 17,870, c = 15)		−0.002*				
9. Self Efficacy (SE) (N = 21, n = 10,658, c = 15)	−0.003*	0.004*				
10. SE: Undergone adapt (N = 14, n = 7290, c = 11)	−0.003**					
11. SE: Intended adapt (N = 10, n = 3648, c = 7)						
12. Social Influence (N = 13, n = 6866, c = 10)						
13. Institutional Faith (N = 20, n = 19,599, c = 12)		0.004***				

*p < 0.1, **p < 0.05, ***p < 0.01.
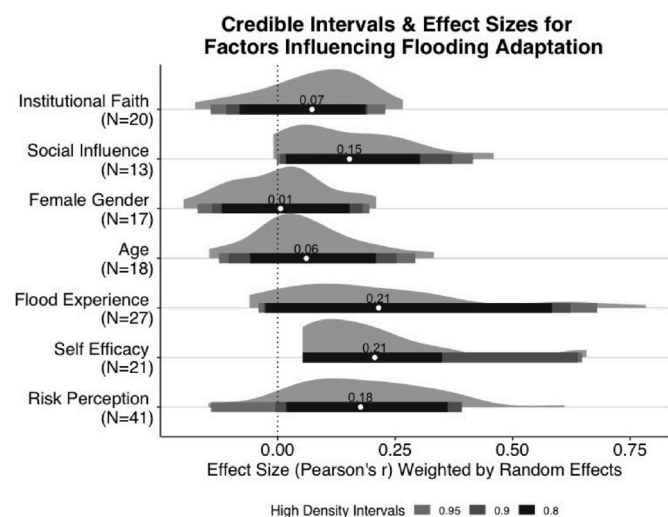
Fig. 1. The Effect Sizes for the 7 primary collected factors motivating flood adaptation (both intention *and* undergone action grouped together) after weighting by random effects.

Fig. 2. Probability density functions for the effect size of risk perception in influencing intention to adapt and undergone adaptation. The mean value for effect size of risk perception toward **intent** is: 0.28 (N = 14 surveys) and for (undergone) **action** is: 0.13 (N = 30 surveys).

may begin to feel sufficiently protected and ignore flood risk after adaptation actions have been taken. Importantly, in contrast to the previous meta-analysis [26], our analysis supports the original assumption [82] regarding feedbacks between adaptation to floods and individual risk perception unfolding over time.

A Bayes' Factor of 16.47 is a "strong" indication that the ES for Risk Perception is greater for intended adaptation to floods than it is for already undergone or concurrent action Jeffreys [50]. For frequentist statistics comparative purposes, a 2-group Mann-Whitney *U* Test, confirms with 99% certainty that the ES of Risk Perception measuring

intended adaptation is statistically different with that of undergone adaptation ($p < 0.01$). We find no statistically significant difference between Self Efficacy and intended vs. undergone adaptation when running the same tests.

3.2. Distribution of the current research

In addition to measuring the distribution of the collected ES and differentiating between intended vs. undergone action, we further considered the implications of the distribution of the current research.

Fig. 3 counts the surveys included in our quantitative meta-analysis as well as those excluded from it for the reasons outline previously (i.e. did not report a transformable effect size or exclusively measured out-migration). The plot depicts the distribution of the research, based on our literature search, overlaid with the distribution of GDP per capita for all the countries in the world. Notably, we observe a strong Global North bias in the survey locations. The economic wealth of a country is intertwined with its culture, and two of Hofstede's cultural rankings - Individualism and Power Distance - are correlated with GDP per capita Hofstede et al. [32]. The implications of this distribution and the lack of work in the global south are discussed below in Sections 3.3 and 4.1.

3.3. Private adaptation and cultural dimensions

To empirically test if there some variance in ES can be explained by national culture we use Hofstede's six cultural rankings. We plot the converted ES of factors motivating individual adaptation against the cultural rankings based on the country where the survey was conducted. In doing so we find that a number of the ES for factors motivating adaptation have a significant relationships with one or more different cultural dimensions. In what follows, we discuss three of the factors motivating adaptation with the most statistically significant relationship with cultural rankings: Flood Experience, Institutional Faith, and (perceived) Probability.

3.3.1. Flood experience and culture

How an individual experiences a natural hazard and the manner in which a society prepares, is impacted, and recovers from an event is strongly influenced by aspects of culture [33,39,51]. In general, personal experience with a flood is a strong indicator of future adaptation [52,53]. Our results indeed support this idea, however the magnitude of the effect appears to be mediated by culture. Several cultural dimensions: *Individualism*, *Power Distance* and *Uncertainty Avoidance* have significant linear relationships with prior Flood Experience's influence on adaptation (Fig. 4).

The *Individualism* dimension is the most highly correlated to the ES of flood experience motivating adaptation, is significant after the Bonferroni correction, and explains the most variance in a linear model. In individualistic societies the 'group' an individual is responsible for, and
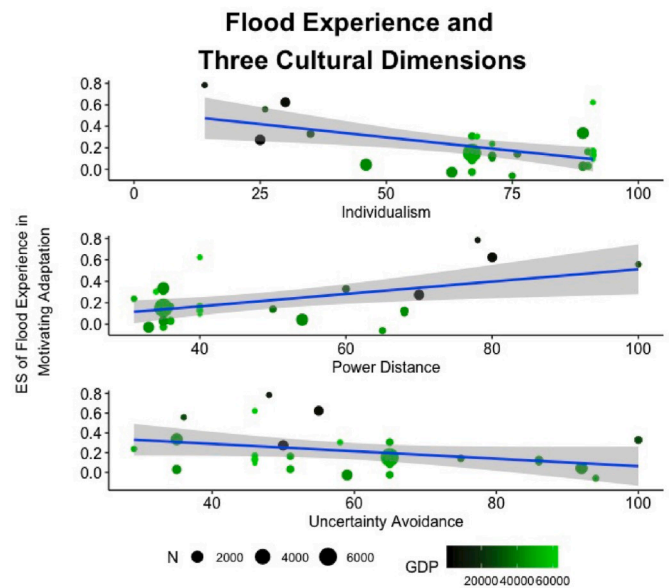
Fig. 4. The effect sizes for flood experience in motivating adaptation plotted against three of Hofstede's cultural dimensions: Individualism (top), Power Distance (middle) and Uncertainty Avoidance (bottom). "N″ is the size of the survey and "GDP" represents GDP per capita for the country in which the survey was conducted.

socially answers to, is smaller than in more collectivist ones. Additionally, in individualistic societies, public areas are less frequently utilized for family and social gatherings [32,54]. Personal connection to a flood affected area is an important factor in determining if a flood experience will influence future adaptation [28,55]. Hence it is possible that a smaller social circle and/or the lessened utilization of public space contribute to the negative relationship that Individualism has with the ES of Flood Experience motivating individual adaptation.

High Power Distance conversely has a positive relationship with flood experience motivating adaptation. This is expected as Power Distance and Individualism generally have an inverse relationship with one another. Furthermore, both cultural dimensions are correlated with GDP per capita (a positive relationship with Individualism and a negative one with High Power Distance). Wealth and culture are inextricably linked in many ways, especially with these two dimensions [32]; p.108, p.132). In Table 2 the results are simple bi-variate associations. Due to the numerous links between culture and wealth and a desire to represent the direct relationship between factors motivating adaptation and cultural variables, we present the associations in the main analysis without controlling for GDP. As a robustness check, we control for GDP and present the findings in Appendix C. Almost all associations between culture and the effect sizes maintain their same level of significance.

GDP per capita however, does indeed contribute to how flood experience affects an individual. It partially represents a nation's capability to allocate resources and provide support to the communities and individuals impacted by floods [56]. These capacities could lessen the traumatic impact of a flood, and thereby contribute to prior flood experience being less of a motivating factor in countries with higher GDP per capita. It is also likely that if a government has more resources to allocate, individuals may expect to receive aid, and thus there could some incentive to 'free-ride' [53]. Despite GDP's importance (see black-to-green gradient in Fig. 4), Individualism is more highly correlated and explains slightly more variance than GDP per capita; further reinforcing the necessity of considering culture in disaster adaptation [19,28,57].

The final cultural dimension to have a significant relationship with flood experience motivating adaptation is *Uncertainty Avoidance*. Uncertainty Avoidance measures how averse to unknown situations
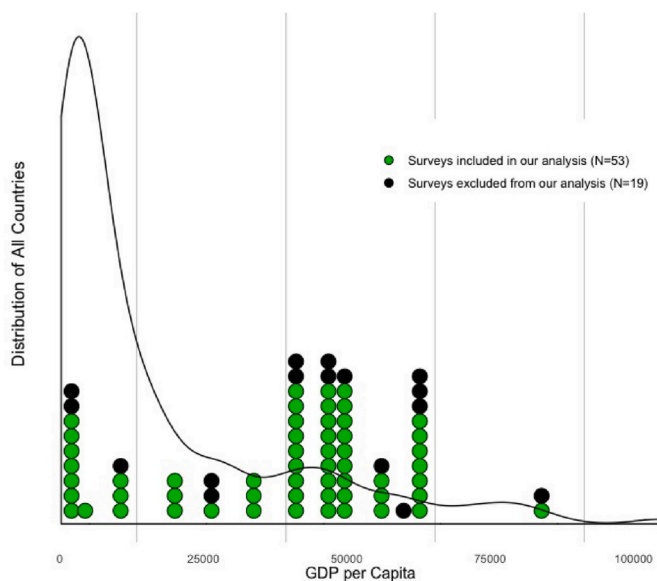

Fig. 3. The probability density curve of global GDP per capita and individual level flooding adaptation studies that were found during the systematic literature search (N = 72) Each dot represents a survey; in some cases several surveys results were published in the same study.

members of a society are. A flood occurrence may serve as a communication vehicle, since people get an updated information on the nature of this hazard event and their vulnerability to it, as also confirmed empirically in the hedonic analysis literature [58]. Hence, experience with a flood and the damage it brings reduces uncertainty surrounding the event. The increased clarity around flooding that follows an event, could result in a lessened adversity to flooding and explain the diminished effect that Flood Experience has in motivating adaption in societies with higher Uncertainty Avoidance. This idea is supported by Ref. [32]; p.198) as they note that individuals from high Uncertainty Avoidance societies can paradoxically engage in risky behavior to in order to "reduce ambiguity" in their lives.

Since Flood Experience shows a statistically significant relationship with multiple cultural rankings, we select a multiple regression model to explain the most variance in the ES of Flood Experience motivating adaptation. Power Distance and Individualism cannot be in the same model due to issues with co-linearity. Thus, using step-wise model building logic, we select Individualism (the most highly correlated cultural factor) and then Uncertainty Avoidance for our model. In Equation (2) we explain the size of the effect of Flood Experience (ES_{Exp}) on adaptation motivation by using the cultural ranking score (C) of the two previously described cultural dimensions - Individualism and Uncertainty Avoidance - with the intercept and error (e).

$$ES_{Exp} = -0.0057(C_{Ind}) - 0.0050(C_{Unc}) + 0.90 + e \qquad (2)$$

Following the data from 27 surveys from 16 countries with the total number of 18,257 respondents, the two cultural dimensions - Individualism and Uncertainty Avoidance - explain 41% (adjusted r^2, $p < 0.001$) of the variance in the size of the effect of Flood Experience motivating adaption. With inclusion in this equation, the p-value of Uncertainty Avoidance increases its significance level to 0.05, further suggesting its value to the model.[3] The credible interval for the ES of Flood Experience motivating adaptation is the largest among all the factors we measured (Fig. 1). The cultural dimensions' explanation of 41% of this variance contributes to a significant increase in accuracy for future cross-national research on the role of hazard experience in the uptake of climate adaptation measures by individuals. Consequently, accounting for the influence of this cultural dimension will create a better frame of reference for climate adaptation policies and disaster research, especially in transferring best practices across countries.

3.3.2. Institutional Faith and power distance

Institutional Faith (Table 1) is another factor consistently reported to influence individual adaptation motivation. Notably, Institutional Faith, has a positive, significant relationship with the cultural dimension *Power Distance*. Our sample of surveys reporting individual flood risk perceptions and actions are drawn from 19,599 respondents, across 12 countries. Within these studies, there is a large over-representation of countries that fall on the "lower" side on the Power Distance scale. This is related to the previously presented skew in research toward nations with higher GDP per capita (Fig. 3). Therefore the positive trend in Fig. 5 is contingent on limited results, giving way to a wide standard error.[4] Yet, the p-value is very strong ($p < 0.001$), significant after the Bonferroni correction, and the trend is theoretically consistent. Therefore,

Fig. 5. The effect sizes for 'Institutional Faith' plotted against the counties' Power Distance rank. ($p < 0.001$ and the adjusted r^2 is 0.33).

we present this finding, noting that further research is needed in countries with high Power Distances.

The larger effect that Institutional Faith has in countries with a higher Power Distance is in-line with Hofstede's characterization of this dimension. In cultures with a high Power Distance, the idea that power is a justification in itself, is rooted at the basis of the society [32]; p.77). Strong leaders are respected, and individuals with less respective power, expect to be told what to do, suggesting that adaptation motivation for individuals in high Power Distance societies may not be innate. The model in Fig. 5 further indicates the effect that government/central media supply information or promotes a particular adaptation action has a much greater inspiring effect in countries where Power Distance is high.

3.3.3. Flood Probability and indulgence

A final relationship between culture and adaptation motivation we wish to highlight is that of *Indulgence* and the perceived *Probability of Flooding* (Fig. 6). Maps reporting flooding probabilities are a common statistic published by governments to alert individuals of their respective flood hazard exposure. The relationship between Indulgence and perceived Flood Probability suggests that this method of communication is not equally effective in all societies and governments and risk managers should be considerate of where their respective society falls on this

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[3] Pearson's r correlation estimate between the two variables is reasonable at 0.27 and the adjusted r^2 between Individualism and Uncertainty Avoidance is 0.06 (with our sample of countries); suggesting co-linearity is not a concern.

[4] Malaysia has a score of 100 to represent the Power Distance in the country. Few surveys have been conducted in countries with such high Power Distance, and as a result, the survey in Malaysia is an outlier. To see how influential the point is we constructed models with and without the data point. The model is statistically significant in both cases, and the slope change is not especially dramatically (0.004 with and 0.005 without.) However, the adjusted R^2 does drop from 0.33 to 0.21, indicating it is indeed an influential point.
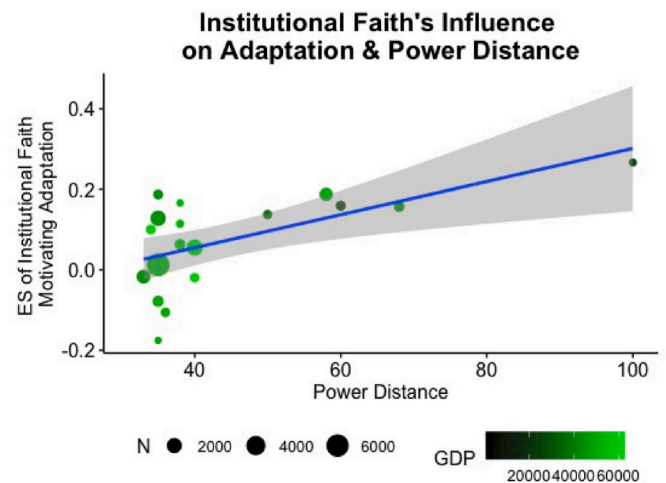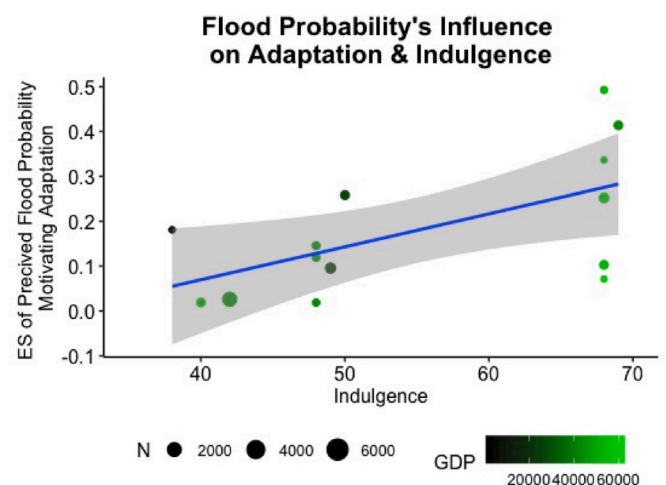

Fig. 6. The effect sizes for the perceived Probability of Flooding plotted against the Indulgence ranking of the country. ($p < 0.05$ and the adjusted r^2 is 0.30).

cultural scale when considering the contents of risk communication.

Indulgence has a significant, positive relationship with the perceived Probability of Flooding motivating adaptation. One of the principle sub-components of an indulgent society is that its members share the belief that they have control over their lives [32]; p.281). It is therefore logical that the elevated self-agency in higher indulgent cultures, has a greater effect in inspiring action. Individuals with higher perceived life control, are more likely to believe that while they cannot lower the objective probability of a flood, they can alter its impact. Hence the effect of probability of flooding on motivation to take private adaptation actions is greater in indulgent cultures. When Masculinity, the other cultural dimension with a statistical relationship with the Probability of Flooding is added to a linear model, both variables lose significance and the adjusted R^2 is less than when just explained by Indulgence.

4. Conclusion

In September 2019 the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [59] revealed that sea level rise is occurring faster than expected earlier, putting even higher pressure on coastal and delta communities around the world to adapt. At the same time, the Global Commission on Adaptation have intensified pleas for taking action to address climate change worldwide. While climate change adaptation at both public and private levels becomes increasingly vital for climate-resilient development and even survival, understanding how individual households' actions and motivations vary across countries remains unclear. This is especially pertinent for flooding - the most costly and devastating climate-driven hazard. Previous work examining disaster risk management has emphasized the influence that cultural factors have on a society's relationship with disasters [60]. On an individual level, flooding adaptation studies across multiple countries further highlight the importance of these context specific factors in influencing behavior [20,21,61]. While these works note the importance of context, they do not specifically attest to patterns across regions or countries. There is an understanding that culture plays a role in individual assessments of risks [19,22], however, a systematic analysis on how different dimensions of culture influence people's perceptions of climate-driven hazards and motivation to adapt to growing risks, is lacking.

4.1. Lack of work in the global south

Culture is a complex, multidimensional concept that can be difficult to measure. These challenges have led researchers to frequently shy away from the inclusion or explicit consideration of culture's influence in climate change adaptation work [33,39]. Yet, culture directly influences many aspects of climate change adaptation motivation and is absolutely essential to include in the discourse [10,62]. Transferring successful cases of climate adaptation from one country to another may prove ineffective should cultural dimensions and differences be ignored. This is particularly troublesome since empirical data on factors motivating adaptation to flooding is collected primarily in wealthy countries. Our review reveals a significant affluence bias in survey locations, towards the Global North (Fig. 3). One may question whether this distribution of surveys reflects the objective flood hazard exposure in the world. However data from EM-DAT [63] shows that floods are common in all regions of the world and that the current state of research is biased toward wealthier countries. Overlaid with statistically significant differences in the effects of culture on private climate change adaptation, this has implications for extrapolating empirical evidence from surveys run in wealthier countries towards anticipating what influences individual adaptation behavior in the Global South where adaptation to climate change is most needed.

This gap presents a scientific challenge in understanding limits of private adaption and global effects of adaptation and unduly puts the Global South -the part of the world disproportionately affected climate

change adversities-at greater risk. For example, a prominent limitation is accounting for private adaptation that influence damage functions in global Integrated Assessment Models; a factor consistently reported as a drawback for this method of analysis [64–66]. Furthermore, professionals who work with disaster policies, management, and research are, themselves, indoctrinated by their own culture and without explicit consideration of the unique context in the area they are working, people tend to view the world through the cultural lens in which they were raised [67]. The bias resulting from the exclusion of culture can lead to inaccurate results and more importantly may increase vulnerability and risks for the affected populations [51,67,68].

4.2. Cultural models

This article address this gap by presenting the results of meta-analysis of surveys conducted globally and reporting on individual decisions to adapt to the most devastating climate-driven hazard: flooding. Our meta-analysis of 53 independent household surveys (N: 38,891) provides empirical evidence in support of considering culture when looking at individual adaptation behavior. When performing meta-regression analysis with Hofstede's cultural rankings as explanatory variables, we find that national level culture indeed affects factors motivating private adaptation behavior towards flooding. For example, there is significant variation in the effect that prior *Flood Experience* has on adaptation motivation is explained by several cultural dimensions: Individualism, Power Distance and Uncertainty Avoidance. The multiple-regression cultural model that predicts the effect of prior Flood Experience on motivating individual adaptation, explains more than 40% of the variance in the collected effect sizes of Flood Experience affecting adaptation. This finding provides a clear incentive for researchers, modelers, and policy makers to utilize the easily accessible national level culture data available for inclusion in their work and models.

Furthermore, two cultural dimensions - *Power Distance* and *Indulgence* - exhibit statistically significant relationships with two factors that influence individual adaption motivation: Institutional Faith and perceived Flood Probability, respectively. The probability of a flood is a commonly published statistic used to communicate hazards to individuals. Notably, how Indulgent a society is has a strong relationship with the degree to which it affects an individuals' motivation to take adaptive action. Furthermore, the degree of Power Distance in a society is a good predictor as to how information and/or action taken by the government and media will influence an individuals' adaptation behavior. Both of these cultural relationships have important implications for researchers and policy makers seeking to motivate citizens to take preparatory action against the adverse effects of climate change. Not all disaster cues are received equally. Climate change strategies and campaigns that are successful in one country cannot be applied to another, without regard for cultural differences. Ignoring this fact will likely lead to less acceptable climate change adaptation measures that are less successful in achieving their intended objectives and may exacerbate the target population's risks.

Equally important are the patterns in relationships between factors affecting individual adaptation to floods and cultural dimensions that we did not witness. Data from our meta-analysis sample does not explain variations in Social Influence and several measures of Risk Perception by any of the Hofstede's cultural dimensions. This does not necessarily indicate that culture has no influence on these factors; as differences in Risk Perception specifically have been found in previous cross cultural contexts [18,22]. Rather it suggests that either more localized culture is at play, and/or a larger sample of surveys across cultures is potentially needed to identify trends in these factors motivating individual adaptation.

4.3. Intention vs. action

Our global analysis of surveys permits us to further investigate of the relationship between individual risk perception and intended versus undergone adaptation to flooding. In contrast to previous analysis based on a smaller sample of surveys [26] we find a strong difference between individual Risk Perception toward undergone and intended adaptation. The higher effect sizes in Risk Perception toward intended adaptation, compared to undergone adaptation is likely due to the feedback the concurrent action has in lowering one's perceived risk once the action is completed. Bubeck et al. [82] propose that longitudinal data would be a revealing method to further investigate this feedback. We agree and additionally suggest that this method would be useful in illuminating the *extent* to which intention leads to action. Furthermore, as demonstrated and discussed by Osberghaus [69]; longitudinal data can be used to show causal effects and datasets with more than two collection points can incorporate a meaningful temporal dimension in the analysis. Several behavioral theories posit intention as a precursor to action [70, 71], however, the extent, and time it takes for individuals to follow through on these intentions remains unclear. Future work should consider the pathway between intention to adapt and the actual undertaking of the action as well the temporal distance from a flood especially in underrepresented global regions.

4.4. Limitations of the study

The research goal of studying the effects of culture on adaptation motivation demanded an extensive international dataset. We determined that a meta analysis was the most appropriate means to accomplish this goal. Like any method of analysis there were limitations, two of which we would like to draw specific attention to.

For our meta-analytic data collection, we collected effect sizes measuring a single construct: adaptation. As is the case with previous meta-analysis' in the field of climate change adaptation [25,26], we grouped all adaptation together into one effect size per study. While this is a necessity in most meta-analysis for statistical reasons (sample size and independence), it contributes to some error. Adaptation motivation very likely differs somewhat with different behavioral choices. Individual adaptation motivation may differ across adaptation actions, which themselves may vary with culture. With the growing number of surveys studying individual motivation for different forms of adaptation, a meta-analysis differentiating across actions becomes a promising direction for future research. Notably, in this article we limit ourselves only to incremental climate change adaptation [72], while major differences in individual motivation is expected between incremental and transformation adaptation.

Secondly, while this article is novel in quantitatively analyzing the impact culture has on individual adaptation motivation, we had to rely on the country-level data in the absence of a systematic global dataset reporting within-country variations in culture. Further, many of the surveys included in our analysis presented findings from respondents located in a multiple cities or regions - inhibiting a finer scale cultural analysis. While all residents of a country in some way, influence and are influenced by the national culture, the strength of the effect can have marked variation depending on the size/homogeneity of the country and the demographics of the sample population. These possible sub-national variations in culture likely contributed to some variance in our estimates.

4.5. Looking forward

In examining the state-of-the-art empirical work on flooding adaptation, we explicitly highlight the need for more research in nations with a smaller GDP per capita. Nations in the Global South, with generally lower GDP per capita, will be disproportionately impacted by climate change. Compared to more economically affluent countries, they are more dependent on private adaptation to floods, given the lower adaptive capacity at national levels to pursue public climate change adaptation measures such as investments in large-scale flood protection infrastructure. Yet, household level surveys eliciting factors motivating individual adaptation to floods are largely underrepresented for this group of nations. In incorporating cultural dimensions, our models provide an increase in accuracy for extrapolating flood adaptation strategies to data scarce countries and regions where individual adaptation research is scarce or non-existent. This work however, should not be seen as a replacement for on-the-ground research. Future work should seek to focus on these data-scare regions, especially in the Global South where the risks of floods and adverse effects of climate change are disproportionately large.

Individual level adaption, complementing government action, is essential to address the increasing flood risk. Understanding how and why individuals adapt is critical for information transmission, motivation, and diffusion of private adaptation in societies. Culture offers a unique insight into the shared patterns of thinking and learning of individuals that can provide important context for their behavior. While culture has previously been used to explain vulnerability to disasters [73], to our knowledge, this is the first article to statistically demonstrate the merit of including culture in climate adaptation analysis when explaining differences in the effects of factors motivating individual level behavior across an adequately large sample of countries. Researchers and policy makers can make use of these findings to better tailor their message, plan, or model and thereby more effectively motivate individual adaptation. We hope that the effect of this work will both inspire further investigation into culture (potentially on a finer scale) and motivated the inclusion of culture as variable in future disaster research.

Data availability

The collected meta-analysis data is publicly available at: htt p://www.sc3.center/

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Appendix A. Cambodia's Cultural Rankings

From Berkvens [40] we have calculated the scores for Cambodia's different cultural dimensions using the following methods:

Individualism (I): Thailand, Hong Kong, S. Korea and Taiwan are averaged due to their comparison to Cambodia. **Power Distance (II)**: Cambodia has "a large power distance." Vietnam and Malaysia, two neighboring countries with high Power Distance are averaged. **Uncertainty Avoidance (III)**: "is higher than Thailand," thus we average Thailand's score with S. Korea's -a country with a very high Uncertainty Avoidance ranking in the region. **Masculinity (IV)**: "a similar position to Thailand," we copied Thailand's score. **Long-Term Orientation (V)**: Cambodia is more short term oriented than Thailand, we copied the Philippians score; a shorter term oriented neighboring country. **Indulgence (VI)**: This dimension was not included in the paper, thus we average Malaysia, Thailand, and Vietnam.

	Hofstede's Cultural Rankings:					
	I	II	III	IV	V	VI
Cambodia's *Estimated* Scores	20	85	75	34	27	46

Appendix B. Equations for transforming effect sizes

Spearman's rho () converted to Pearson's r [74].

$$r = 2\sin\left(\frac{\pi}{6} * \rho\right) \tag{3}$$

Chi Squared (χ^2) (df = 1) converted to Pearson's r [75].

$$r = \sqrt{\frac{\chi^2}{n}} \tag{4}$$

Odds Ratio (OR) converted to Pearson's r [76].

$$r = \frac{\sqrt{OR} - 1}{\sqrt{OR} + 1} \tag{5}$$

Kendall's tau () converted to Pearson's r [77].

$$r = \sin(0.5\pi * \tau) \tag{6}$$

beta () converted to Pearson's r (y = 1 when is greater than or equal to zero, and 0 when is smaller than zero) [25,78].

$$r = \beta + 0.05y \tag{7}$$

Logistic regression coefficients () converted to Pearson's r [76,79].

$$OR = e^{\lambda} r = \frac{\sqrt{OR} - 1}{\sqrt{OR} + 1} \tag{8}$$

Pearson's r to Fisher's Z for variance stabilizing and then back to Pearson's r for reporting the values [38].

$$Z = 0.5 * ln\left(\frac{1 + r}{1 - r}\right) r = \frac{e^{2Z} - 1}{e^{2Z} + 1} \tag{9}$$

Appendix C. Control for GDP

Table 3
Here we list the p-values (< 0.1), for the variables that have a relationship with Hofstede's Cultural Rankings after we have controlled for GDP per capita. We did this by multiplying the log of GDP per capita by the respective effect sizes and then testing the variables' relationship with the different cultural dimensions. (**I**): Individualism - Collectivism, (**II**): High - Low Power Distance, (**III**) High - Low Uncertainty Avoidance, (**IV**): Masculinity - Femininity, (**V**): Long - Short Term Orientation, (**VI**): Indulgence - Restraint.

	Hofstede's Cultural Rankings:					
	I	II	III	IV	V	VI
1. Risk Perception (RP)						
2. RP: Undergone adapt						
3. RP: Intended adapt						
4. RP: Probability		0.09		0.07		0.02
5. RP: Damage					0.06	
6. Flood Experience	0.02	0.03	0.08			
7. Age		0.07				
8. Gender (Female)		0.06				
9. Self Efficacy (SE)	0.09					
10. SE: Undergone adapt	0.07					
11. SE: Intended adapt						

Table 3 (*continued*)

	Hofstede's Cultural Rankings:					
	I	II	III	IV	V	VI
12. Social Influence						
13. Institutional Faith		0.007				

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