ORIGINAL ARTICLE

Examining the impact of climate information access on adaptive behaviors during heatwaves: insights from Central Vietnam

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ABSTRACT

This study focuses on the correlation between the different sources of climatic information involving the Short Message Service (SMS), social networks, local governments, online platforms, and workplaces and the individual adaptation measures concerning heatwaves. The survey data were obtained from four areas in central Vietnam involving 400 respondents. We used propensity score matching (PSM) to estimate the average treatment effect on the treated, aiming to mitigate selection bias. Findings indicate that the availability of various information sources encourages communities to address rising heat stress, with information sourced from SMS, social media platforms, local authorities, and workplaces being prominent. The findings signal the need to increase the visibility of heatwave data, which can change people's behavior to reduce climate risks. In order to accomplish this goal, it is important to focus on climate change information sharing through platforms such as social networks, local administration offices, and the workplace in coping with climate change-related threats.

Key words:
Information sources; adaptive behaviors; heatwaves; propensity score matching; Vietnam

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INTRODUCTION

Climate change poses a looming threat, poised to exacerbate existing conditions and significantly increase mortality rates while hindering labor productivity, particularly in the most vulnerable parts of society.[1] However, these consequences are often not readily recognised, but are gradually showing as detrimental outcomes over time. Heatwaves, present substantial physical, mental, and economic hazards to humanity.[2–5] The year 2019 was ranked as the second warmest globally in the last 140 years, with an average temperature deviation of +0.95°C.[1] Heatwaves account for 40% of the top ten deadliest natural disasters, with South Asia bearing a disproportionately high number of fatalities.[5,6] The results obtained from numerous studies indicated that Vietnam has been experiencing an increase in the average temperature in recent years. Vietnam's average temperature has risen at an average rate of 0.26 degrees Celsius per decade.[7] The average temperature increase in Vietnam is also higher when compared globally, showcasing a warming trend exclusive to Vietnam. Some projections suggest that Vietnam is likely to experience an annual average temperature rise of between 1.6 and 3.7 degrees Celsius by the end of the 21st century.[8] The literature widely explores the trends and patterns of Extreme Heat Events (EHEs), such as the rising rates and intensification of heatwaves in different countries and the consequences all over the world. It is well-documented that heatwaves have taken more than 166,000 lives between the years 1998 and 2017, including the 2003 European heatwave recorded to have claimed over seventy thousand lives.[9]

To mitigate the negative health impacts of heatwaves, adopting measures to cope with them is crucial. [1, 5, 10–12] Adaptation emerges as the primary strategy for preventing or mitigating the health consequences of heatwaves.[13] These adaptive measures span individual and community levels, encompassing actions like maintaining proper hydration, seeking refuge in air-conditioned environments, and refraining from strenuous outdoor activities during peak heat periods. At the community level, interventions include executing heat emergency response strategies and establishing designated cooling facilities for populations at heightened risk.[6, 14, 15] Prevention and mitigation of the health impacts of heatwaves requires coordinated actions on individual and societal levels, early heatwave warning systems, reliable heat alarms, and constant fine-tuning of preventive measures to correspond to the current tendencies of heatwaves. Applying these measures will help concerned communities minimize the adverse health impacts associated with heatwaves.

Access to weather-related information sources such as SMS, social media platforms, local authorities, and workplaces, serves as a vital foundation for individuals to take various actions aimed at protecting their well-being during heatwaves. [6,15] Proactive measures include maintaining proper hydration, seeking cooler surroundings, using fans or air conditioning, wearing lightweight attire, and minimizing outdoor activities, especially during peak heat periods. Communities also implement proactive measures by establishing cooling centers or public areas equipped with air conditioning, providing safe havens for those without access to cooling amenities at home. Moreover, the introduction of customized instructions tailored to vulnerable populations strengthens these efforts.[11,13] Vietnam has a well-developed mobile phone signal coverage network, with strong 3G, 4G, and 5G services in urban areas and

rural regions, covering 99.9% of the population and over 85% of the population using mobile phones. [16]

Despite the availability of information, the literature suggests that the mere acquisition of knowledge does not necessarily translate into behavioral changes, contributing to the existence of a "motivation-behavior" gap. Therefore, it is crucial to examine how access to different information sources interacts with adaptive behaviors during extreme heatwaves. Consequently, the objective of this study is to investigate the relationship between various sources of information and adaptive behaviors for coping with heatwaves, with significant implications for the development of more effective strategies at local and global scales.

METHODS

Study design, study areas, and data collection

Because of the changing climate, people from the central part of Vietnam, especially from the region of the Central Coast are starting to experience health issues related to heat. Those living in this area have been subjected to extreme conditions that have seen them suffer increased instances of heat-related ailments such as dryness, exhaustion, and heat stroke.[17] Further expected rise in temperatures will have a significant effect on the central provinces which include; Quang Binh, Thua Thien Hue, Binh Dinh and Khanh Hoa provinces where temperatures usually go higher than 37°C and occasionally reaching even higher levels.[18] These harsh conditions are detrimental to health of the people and also affect normal living and functioning in Central Vietnam.[9, 17] Therefore, the present study focuses on Central Vietnam, a region particularly vulnerable to the impacts of heatwaves and other extreme climate events.

A semi-structured questionnaire was employed, and a stratified sampling technique was used across four provinces in central Vietnam: Quang Binh, Thua Thien Hue, Binh Dinh, and Khanh Hoa (Figure 1). Respondents were selected from individuals hospitalized in major hospitals within these provinces, ensuring that respondents were familiar with the effects of heatwaves. The primary data collection was conducted face-to-face in summer 2022. It included inquiries about strategies used to minimize heatwave effects, and information sources accessed, such as SMSs, social networks, local governments, online platforms, and workplaces. Additionally, socioeconomic characteristics and knowledge about heatwaves and their impacts on individuals were collected. A total of 400 respondents participated in the survey, and 394 valid responses were used for further analysis after the data-cleaning process.

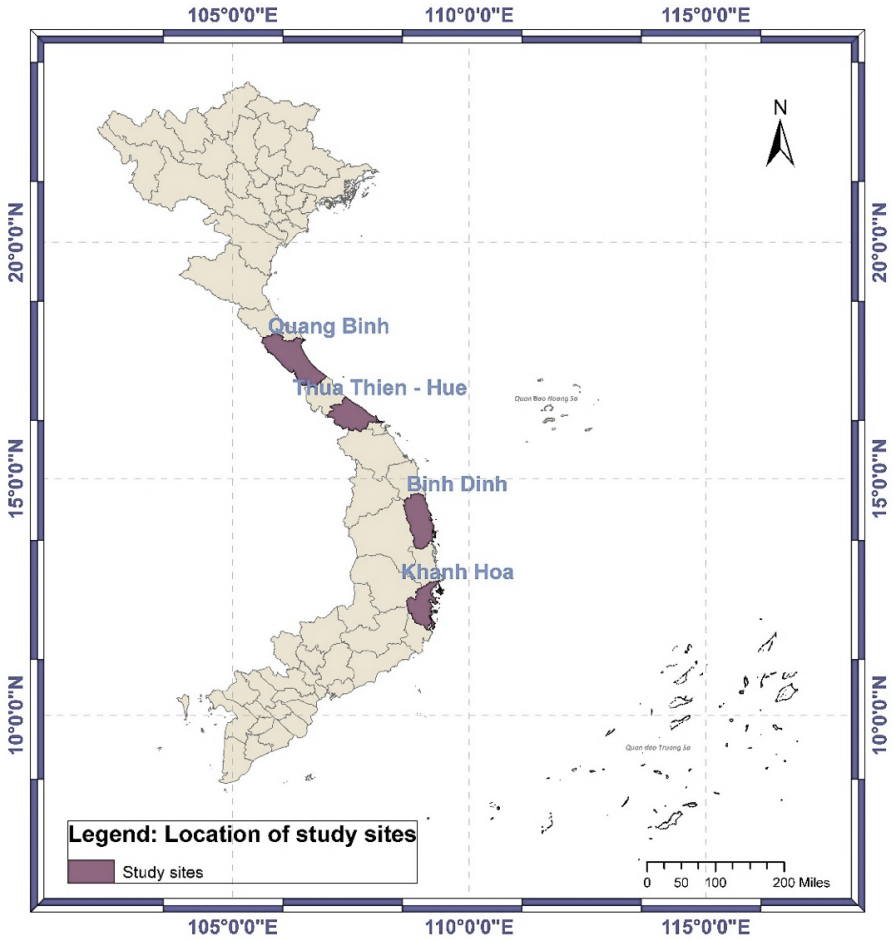

Figure 1. Location of study sites (*Source: Authors)*

Variable selection

In this study, our variable selection process was informed by a thorough review of existing literature on heatwave adaptation and its influencing factors.[5, 19–21] The findings from this review highlighted several crucial elements that shape individuals' adaptive behaviors during heatwaves, including the sources of information contributing to these behaviors. [5,21,22] Firstly, previous research consistently underscores the pivotal role of access to information in influencing adaptive behaviors during heatwaves. Various sources, such as local government announcements, workplace policies, social networks, and online platforms, have been identified as significant influencers shaping responses to extreme heat events. [22] Additionally, the literature emphasizes the significance of socio-demographic factors in heatwave adaptation.[23] Variables like household income, education level, age, and employment status have been shown to affect individuals' capacity to access information and implement adaptive measures effectively.[22,24] Moreover, individual perceptions and beliefs about heatwaves play a crucial role in shaping adaptive behaviors.[23,25,26] Factors such as beliefs about risk severity, the efficacy of adaptive measures, and vulnerability perceptions influence decision-making during extreme heat events. Additionally, the economic aspect, such as the cost of illness, affects individuals' decisions regarding coping strategies. Thus, we

included these variables in our analysis to assess their impacts on adaptive behaviors.

In the study area, access to information from diverse sources, including SMS, work organizations, Internet platforms, social networks, and local government, significantly influences adaptive behaviors in response to heatwaves. Samples of heatwaves warning messages at the study sites are shown in Appendix 1. Access to timely alerts, warnings, and advisories via SMS prompts individuals to take proactive measures such as staying indoors, staying hydrated, and minimizing outdoor activities during peak heat periods. Information from work organizations can offer guidance on adjusting schedules to avoid heat exposure. Similarly, online resources and social networks contribute to increased awareness about heatwave risks and appropriate adaptive measures. Local government agencies play a crucial role in disseminating forecasts and emergency response plans, and ensuring access to cooling centers for vulnerable populations. Communities with better access to information are likely to exhibit higher levels of preparedness and resilience to heatwaves.

Ethical approval

The work received approval from the Human Research Ethics Committee of Hue College of Medicine and Pharmacy (Vietnam) and Queensland University of Technology Research Ethics Committee (Approval number: H2021/016).

Statistical analysis

We used Stata version 17.0 (Stata Corp, College Station, TX, USA) to calculate the average treatment effect on the treated (ATT). It is crucial to compare outcomes between households with access to information and those without. In a randomized experimental design, ATT measures the difference in average outcomes between the group receiving treatment (access to information) and the group not receiving treatment (non-access). However, since information access in our sample is based on individual choice rather than random assignment, this approach is not feasible. We must account for self-selection bias in our analysis. Without experimental data, non-experimental methods such as instrumental variable (IV), propensity score matching (PSM), difference-in-differences (DID), or PSM-DID are more appropriate for estimating the average treatment effect (ATT).

Instrumental variables (IVs) are commonly used to address selection bias stemming from unobserved variables. The IV method requires the IV to be correlated with endogenous variables but uncorrelated with the error term. However, finding a high-quality instrument is challenging in empirical studies. If the IV is invalid, estimators based on IV may exhibit greater bias compared to ordinary least squares (OLS) estimators. Therefore, we opt not to use the IV strategy and instead consider PSM as the most suitable option. Propensity score matching (PSM) can alleviate selection bias by comparing individuals with similar observed characteristics but differing levels of information access.[27–30]

To apply the PSM method, the initial step involves estimating the likelihood that a household has access to information sources (such as SMS, social networks, local government, other internet sources, and work organizations) regarding heatwaves. This estimation is performed using a logit model, considering a specific set of covariates. Consequently, both the treated group (those who received treatment) and the control group (those who did not receive treatment) will have their own estimated likelihood of access, which is referred to as the propensity score. We used a logit model (Equation 1) with STATA function logit for estimation as follows:

$$Pr(X) = logit(D=1) = \alpha + \beta X \quad (1)$$

where D denotes the treatment status of respondents, signifying their access to information sources such as SMS, social networks, local government, other internet sources, and work organizations. The vector X includes observed attributes that are not influenced by this treatment.

Before implementing matching, it is essential to fulfill two vital prerequisites. First, it is necessary to establish the common support area, which includes the range of propensity score values where both the treated (access) and control (non-access) groups are present. To handle cases where a specific household in the access group does not have a corresponding match in the non-access group, individuals with propensity scores that are higher than the maximum or lower than the minimum of the non-access scores are eliminated. By employing this method, we ensure that only households located within the shared support region are utilized for matching, thereby avoiding skewed comparisons between families that cannot be compared. The second criterion entails meeting the balancing property test[31], which states that observations with identical propensity scores should have the same distribution of observable properties (X variables), regardless of their access status. There are no established guidelines for determining acceptable levels of imbalance in propensity scores. However, it is generally recommended that the maximum standardized difference for certain covariates should ideally fall between 10% and 25%.[31]

The last phase involves pairing the treated (access) with non-treated (non-access) based on comparable tendencies. The expression for the average treatment effect on the treated (ATT) using the propensity score matching (PSM) estimator, is given in Equation 2:

$$ATT^{PSM} = E\{(Y_{iA}|D = 1, P(X))\} - E\{(Y_{iN}|D = 0, P(X))\} \quad (2)$$

where ATT measures the effect of access to information sources on the observed outcomes of access. D denotes the treatment (access to information sources about heatwaves) status of the household. Y_{iA} and Y_{iN} are ATT measures of the effect of access to information sources about heatwaves on the observed outcomes of the access, X is a vector of the observed characteristics, $P(X)$ denotes the propensity score of each household given the observed covariates, and ATT^{PSM} is the difference in outcomes between the access and non-access appropriately matched by the propensity score $P(X)$.

RESULTS

Characteristics of the respondents

Table 1 presents descriptive statistics for the variables examined in the study. The outcome variable, the number of adaptive behaviors adopted by individuals, showed a mean of 5.75 with a standard deviation of 1.61. In terms of treatment variables, the data indicated varying levels of access to information from different sources. Notably, the highest mean was observed for access to information from the local government (0.84), followed by work organizations (0.79), other Internet sources (0.76), social networks (0.74), and SMS (0.75).

Table 1. Descriptive statistics

Variables	Mean	Std. dev.	% Yes
Outcome variable			
Adaptive behaviors (number)	5.751	1.609	-
Treatment variables – information sources			
Access to information from SMS (1= Yes, 0= otherwise)	0.746	0.435	74.62
Access to information from the Work organization (1= Yes, 0= otherwise)	0.786	0.410	78.68
Access to information from Other Internet sources (1= Yes, 0= otherwise)	0.761	0.426	76.14
Access to information from Social networks (1= Yes, 0= otherwise)	0.736	0.441	73.60
Access to information from Local government (1= Yes, 0= otherwise)	0.842	0.364	84.26
Control Variables			
Ln(Household income) (million VND/month)	0.447	0.499	
Age of household head (years)	65.72	15.41	
The educational level of the household head (scale 1-5)	2.563	1.384	
Perception about the heatwaves (scale 1-5, unlikely to very likely)	3.619	0.729	
Agreement about no evidence that heatstroke/heatstroke causes respiratory illnesses (1= Yes, 0= otherwise)	0.705	0.456	
Agreement about older adults and children are especially vulnerable during peak/extended heatwaves (1= Yes, 0= otherwise)	0.959	0.197	
Agreement about Prolonged heatwaves in urban areas has less serious effects on people's health than in rural areas (1= Yes, 0= otherwise)	0.888	0.315	
Types of job (1= outdoor; 0= indoor)	0.375	0.484	
Number of days for treatment heat-related illness (days)	8.157	4.569	
Cost of testing the disease (million VND/year)	13.10	0.932	
Number of time for hospitalizations (time/year)	2.137	1.625	
Costs for food during treatment (million VND/year)	11.60	1.383	
Number of days staying at the hospital (days)	15.41	14.28	
Number of days the caregiver participates in care (days)	11.53	10.80	

Moreover, we included several control variables such as household income, age of the household head, educational level of the household head, perception of heatwaves, and agreement on various statements related to heatwaves. Additionally, other control variables, such as types of jobs, number of days for treatment, cost of testing the disease, number of hospitalizations per year, costs for food during treatment, number of days staying in hospital, and number of days the caregiver participated in care, were encompassed. The study recruited participants with an average age of 65.7 years, with a relatively high standard deviation of 15.4 years. In terms of education, the average score of 2.6 on a 5-point scale suggests a moderate level of education among participants. Most importantly, their perception of heatwaves leaned towards being a threat, with an average score of 3.6 on a scale of 1 (unlikely) to 5 (very likely). Interestingly, the data on job types (1= outdoor; 0= indoor) shows a slight skew towards outdoor jobs, with an average score of 0.375. The study also delved into the healthcare burden associated with heat-related illnesses. On average, participants were hospitalized 2.14 times a year for such illnesses, with some variation as shown by the standard deviation of 1.63. The average treatment lasted 8.157 days.

Adaptive behaviors used by respondents

Table 2 presents the prevalence of adaptive behaviors used by respondents to mitigate the effects of heatwaves, based on data collected from a sample of 394 respondents. Among these behaviors, the most commonly reported action was the purchase or use of fans or ceiling fans, with a notable 94.42% of respondents engaging in this practice. Following closely, a significant portion of respondents (93.91%) chose to wear thin clothes as a measure to alleviate the effects of heatwaves. Other prevalent adaptive behaviors included staying indoors or avoiding direct sunlight (81.22%), planting trees around the house (84.26%), and adjusting work schedules to cooler parts of the day, either early morning or late evening (59.39%). On the other hand, fewer respondents reported participating in activities such as swimming in a pool (26.40%) or upgrading/repairing house features like thick walls or insulation (34.52%). These findings provided valuable insights into the diverse strategies individuals employed to adapt to heatwaves, offering a nuanced understanding of the various approaches taken to mitigate the impacts of extreme heat.

Table 2. Adaptive behaviors during heatwaves adopted by respondents

Adaptive behaviors	% Yes
Buy/use air conditioner	58.38
Buy/use fan/ceiling fan	94.42
Plant trees around the house	84.26
Stay indoors/stay out of the sun	81.22
Shower several times a day	42.64
Use thin clothes	93.91
Work early in the morning or late in the evening	59.39
Swim in pool	26.40
Upgrade/repair house features (e.g., thick walls, high ceilings, insulation)	34.52

Source: Calculated by authors from the survey.

Factors associated with accessing information about heatwaves

Table 3 delves into the parameters associated with accessing information about heatwaves through multiple channels, including SMSs, social networks, local governments, other online sources, and work organizations. Using a logit estimation model with marginal effects, the results shed light on various factors that influenced the accessibility of heatwave information. Notably, age, education level, employment type, treatment period, and caregiver engagement significantly impacted the likelihood of obtaining heatwave information via SMS.

The findings revealed a generational preference for receiving heatwave information through SMS, with younger age groups showing a higher propensity. Specifically, as the age of the household head increased, there was a slight decrease (-0.3%) in the probability of accessing SMS information. Older people appear to be more at risk from heatwaves.[32] The results show that females and those who are 55 years and older are the most likely to be affected by heatwaves.[33]

Furthermore, individuals employed in outdoor occupations exhibited a stronger inclination (+0.293) for receiving heatwave updates via SMS, enabling them to proactively mitigate heat-related challenges in their work environment. In addition, a noteworthy correlation emerged between patients undergoing therapy and their preference for SMS-based heatwave information. A prolonged duration of

medical treatment correlated positively with the likelihood of seeking such information, as did an increased number of caregiving days. This trend underscored the role of SMS alerts in helping individuals develop effective strategies to mitigate health risks and potentially reduce healthcare expenses associated with heatwave-induced illnesses. Shifting the focus to social networks, we found that younger demographics leaned more towards these platforms for heatwave information, owing to their familiarity and technology accessibility. Interestingly, individuals with a heightened awareness of heatwave impacts exhibited lower reliance on social networks, potentially indicating greater trust in governmental or organizational sources. Furthermore, occupational factors significantly influenced social network usage for information-seeking, with outdoor workers showing a 1.34% increase in favor of this communication channel. Our findings also underscore the impact of medical treatment costs on information-seeking behavior via social ties.

Additionally, Table 3 highlights factors influencing the acquisition of information from local government sources. Educational attainment is negatively correlated with reliance on local government channels for heatwave information, possibly due to increased knowledge facilitating access to alternative sources. Conversely, higher education levels positively influenced information acquisition from online sources and professional institutions. Furthermore, variables like job type, treatment duration, and healthcare expenses significantly shaped individuals' preferences for different information channels, underscoring the multifaceted nature of heatwave awareness and adaptive behavior strategies.

Table 3. Factors linked to access to different sources of information for heatwaves from propensity score estimation (logit model)

Variables	SMS	Social networks	Local government	Other Internet source	Work organization
Ln (Household income)	-0.069	0.093	-0.057	0.188***	-0.154***
	(0.061)	(0.062)	(0.051)	(0.062)	(0.058)
Age of household head	-0.003*	-0.006***	-0.000	-0.002*	-0.003*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
The educational level of the household head	0.062***	0.027	-0.035*	0.046**	0.049**
	(0.022)	(0.021)	(0.019)	(0.020)	(0.021)
Perception about the heatwaves	-0.041	-0.076***	-0.033	-0.088***	0.002
	(0.029)	(0.028)	(0.026)	(0.028)	(0.029)
Agreement about no evidence that heatstroke/heatstroke causes respiratory illnesses	-0.053	-0.029	0.079*	-0.005	0.045
	(0.046)	(0.044)	(0.043)	(0.042)	(0.047)
Agreement about older adults and children are especially vulnerable during peak/extended heatwaves	-0.225*	-0.141	-0.015	-0.054	-0.009
	(0.125)	(0.124)	(0.099)	(0.124)	(0.102)
Agreement about Prolonged heatwaves in urban areas has less serious effects on people's health than in rural areas.	-0.099	-0.045	-0.145**	-0.121*	-0.075
	(0.070)	(0.068)	(0.074)	(0.071)	(0.072)
Types of job	0.293***	0.134***	0.139***	0.104**	0.095**
	(0.049)	(0.046)	(0.042)	(0.045)	(0.046)
Number of days for treatment	0.023***	0.017***	0.012**	0.013***	0.021***
	(0.006)	(0.005)	(0.005)	(0.005)	(0.006)
Ln (Cost for testing the disease)	0.016	0.049**	-0.009	-0.006	-0.026
	(0.022)	(0.022)	(0.020)	(0.022)	(0.023)
Number of hospitalizations a year	-0.004	0.035*	-0.007	0.025	0.013
	(0.023)	(0.019)	(0.019)	(0.018)	(0.021)
Ln (Costs for food during treatment)	-0.017	0.055***	-0.017	0.044***	0.004
	(0.021)	(0.016)	(0.018)	(0.015)	(0.015)
Number of days staying at the hospital	-0.005	-0.004	-0.003	-0.005*	-0.002
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Number of days the caregiver participates in care	0.008**	-0.005	0.004	-0.001	-0.000
	(0.004)	(0.003)	(0.003)	(0.003)	(0.004)

Notes: Each Column of result is a separate estimate of equation (1) by using logit estimation (First stage of Propensity Score Matching).
Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Effect of access to various information sources on adaptive behaviors

Table 4 outlines the relationships between different sources of heat wave information and the adoption of adaptive measures aimed at mitigating heat-related health issues. To address potential selection bias, PSM was employed to evaluate the impact of accessing or lack of access to information on individuals' decision-making regarding adaptive strategies. Prior to matching, individuals seeking heat wave information typically utilized various adaptive measures to safeguard themselves from the adverse effects of high temperatures. Results demonstrate statistically significant impacts of information obtained via SMSs, social networks, local governments, and work organizations, with coefficients of 0.244, 0.421, 0.401, and 0.178, respectively. However, adjustments were made to certain calculations using the PSM method, particularly concerning the influence attributed to short message services (SMSs), other online sources, and workplaces. Post-PSM analysis revealed that individuals with access to information from social networks, local governments, and work organizations tended to employ

more adaptive strategies compared to those without such access. This disparity between the two groups was statistically significant, with a p-value of 1%, particularly regarding information sourced from work organizations. This implies that multiple channels providing information on heatwaves encouraged individuals to embrace a broader spectrum of adaptation techniques, consequently mitigating the health impacts associated with heatwaves. When comparing the results, it is evident that acquiring information from social networks has the highest effect, signifying that social networks may be the optimal channels of communication for increasing heat wave adaptation techniques. Popular social media platforms such as Facebook, and Zalo in Vietnam can provide timely information updates, people-to-people support, and regional management strategies. Media literacy, and establishing a fact-checking mechanism are necessary for effective use of social media while ensuring its authenticity for individuals.[9]

Table 4: Effect of access to various information sources on adaptive behaviors for heatwaves

Variables	SMS	Social networks	Local government	Other Internet source	Work organization
	Coef.	Coef.	Coef.	Coef.	Coef.
Accessing information from various source (Yes= 1; otherwise= 0) - Unmatched	0.244**	0.421***	0.401***	0.132	0.178*
	(0.109)	(0.109)	(0.130)	(0.114)	(0.099)
Accessing information from various source (Yes= 1; otherwise= 0) - Matched	0.163	0.621***	0.337**	0.140	0.187*
	(0.122)	(0.127)	(0.145)	(0.122)	(0.113)

Notes: Each coefficient is a separate estimate of equation (2)
Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

DISCUSSION

Access to information plays a pivotal role in safeguarding public health during heatwaves by facilitating the use of adaptive behaviors. Extreme weather events pose significant risks to human well-being, including heat-related illnesses such as heat exhaustion, heatstroke, and dehydration. Timely and accurate information on heatwaves empowers individuals, communities, and authorities to proactively mitigate these health risks. Armed with knowledge, individuals can adjust their behaviors, such as modifying outdoor activities during periods of intense heat, dressing appropriately, and seeking refuge indoors in air-conditioned spaces when necessary. Information serves as a valuable resource that enhances individuals' capacity to make informed decisions, thereby strengthening their ability to adapt to changing climatic conditions.[34] However, despite efforts to disseminate information on climate change, studies suggest that its impact on the use of adaptation measures has been limited.[35] To address the issues of selection bias and endogeneity in this study, the PSM technique was applied, enabling us to establish a positive relationship between the heatwave information and the utilization of adaptive climate change strategies. However, the standard PSM done using cross-sectional data can only account for relevant characteristics and not the relevant traits that impact adoption and outcomes not accounted for by observables. Other approaches, such as panel data can be employed in order to account for fixed time omitted variables and overcome the limitations of the present research. Nevertheless, this research provides new insights, and these findings underscore the

importance of information acquisition when it comes to addressing climate change and overhauling disaster risk management because of elevated heat threats.

The research findings that arise from the use of PSM also establish that access to information from social networks, local government agencies and employers' organizations significantly affects the higher level of use of adaptive measures. This underscores the paramount importance of the availability of a wide range of necessary sources of information when designing sustainable and adaptive heat wave risk mitigation strategies. Our findings are in line with past studies regarding the effect of information sources on access to other adaptive measures needed for preventing the health effects of heat. A review of recent literature shows that information on heatwaves can be gathered from social networks to determine the general perception of the public, which in turn, can be used to formulate more specific measures that are suited for adaptation to the effects of heatwaves.[33] Furthermore, our finding is in line with other research suggesting that local governments bear significant responsibilities in raising awareness of heat health hazards and undertaking actions to safeguard against the effects of heat and heatwaves.[36] Therefore, our findings are in line with the prior research, which points out that in work environments, communication plans and activities are vital for enhancing organizational resilience and adaptation to extreme events such as heatwaves.[37]

Moreover, our findings indicate that the mere presence of information does not automatically translate into behavioral change; rather, the manner in which information is conveyed and utilized is crucial.[38] While information fulfills immediate needs, it also plays a vital role in helping communities anticipate and respond to climate change.[39] Hence, there is a pressing need for comprehensive investigations to evaluate the influence of access to adaptable measures for climate change. The findings of this study unveil a significant correlation: greater access to diverse information sources motivates individuals to actively embrace adaptive techniques to counter the hazards posed by climate change, particularly heatwaves.

Furthermore, this study underscores the significant impact of information obtained from social networks and local authorities on driving changes in behaviors related to the adoption of adaptive measures for heatwaves. PSM estimations highlight the heightened statistical significance of information acquired through social connections and local governmental channels compared to other sources such as SMS, web resources, or workplace affiliations. This finding aligns with prior research, further underscoring that the influence exerted by sources closely linked to social networks and local governance systems is notably stronger.[13] These insights bridge gaps in understanding the causal relationship between access to information sources on heatwaves and the adoption of adaptive behaviors. They can inform policymakers on effective strategies to disseminate information about climate change and encourage the implementation of coping mechanisms to safeguard public health.

The following strategies may be considered to implement our study's findings in relation to the impact of access to information sources regarding heat wave adaptation at both the policy and community levels. Under the policy domain, it is important to integrate heat health details into policy coherence and broad adaptation frameworks. This integration can warn the authorities of dangerous heat, helping them choose appropriate actions that would provide

significant public health benefits at a relatively low cost. Moreover, creating systems for heatwave response based on surveillance helps local health care practitioners receive specific information regarding health complications owing to heatwaves.[17]

Thus, communication at the community level should be more effective in terms of identifying and enhancing community capacities to tackle future heatwaves.[40] Studies show that heat alerts that are made freely available can successfully minimize the chance of an individual being exposed to extreme heat when the weather is hot, thereby emphasizing the significance of disseminating information in an effort to minimize heat related adverse health impacts. In addition, educating the public on measures that could be taken when facing excessive heat conditions, like drinking plenty of water and avoiding any outdoor activities during hot seasons is crucial. [41]

RECOMMENDATIONS

The findings from this study reveal that information from diverse sources motivates communities to embrace more flexible approaches, with social networks and local governments playing particularly significant roles. Specifically, individuals who have access to information from social networks and local governments are more likely to use adaptive behaviors in response to heatwaves compared to those who rely solely on other sources. Building on these results, interventions can be implemented to elevate the importance of heatwave data, thereby influencing human behavior to mitigate climate change hazards.

The dissemination of climate change knowledge through channels like social networks and local governments is crucial. Additionally, continuous improvement in weather forecasting and its accuracy empowers individuals and groups to optimize their adaptive strategies, thereby reducing potential costs associated with missed opportunities. Moreover, enhancing the perceived value of information obtained from sources such as SMS alerts, online platforms, workplace communications, and traditional media channels is essential for developing and implementing a diverse range of coping mechanisms to address climate change challenges.

While this study provides new insights, future research should address some limitations. For instance, standard PSM using cross-sectional data can only control for the selection of observed covariates, not unobserved heterogeneity that may affect adoption and outcomes. Utilizing panel data or alternative methods could better control for time-invariant unobserved heterogeneity when estimating the causal relationship between information access and adaptive behaviors during heatwaves. Additionally, further investigation into the differential impacts of various information sources on different demographic groups could provide valuable insights into tailoring climate change communication strategies.

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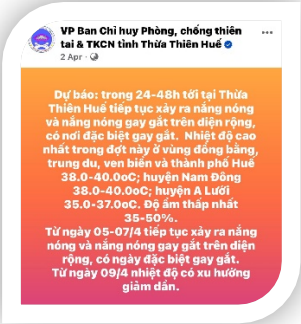
Appendix 1: Samples of heatwaves warning messages at the study sites

Sample messages	Translation
[Trung tâm Dự báo KTTV quốc gia] 1. Cảnh báo: Ngày 24/4, nắng nóng dịu dần ở phía Tây Bắc Bộ và khu vực từ Thanh Hóa đến Phú Yên. Nắng nóng ở Nam Bộ còn có khả năng kéo dài. 2. Cảnh báo cấp độ rủi ro thiên tai do nắng nóng: cấp 1 3. Dự báo tác động của nắng nóng: nắng nóng còn có thể gây tình trạng mất nước, kiệt sức, đột quỵ do sốc nhiệt đối với cơ thể người khi tiếp xúc lâu với nền nhiệt độ cao. *Zalo warning message from National Center for Hydrometeorological Forecasting*	[National Center for Hydrometeorological Forecasting] 1. Warning: On April 24th, heatwaves will gradually ease in the Northwest region and the area from Thanh Hoa to Phu Yen. Heatwaves in the South may persist. 2. Heatwave disaster risk warning level: Level 1 3. Forecast of heatwave impacts: Heatwaves can also cause dehydration, exhaustion, and heatstroke for people exposed to high temperatures for extended periods.
 *Facebook warning message from Provincial Steering Committee for Prevention and Control of Natural Disasters and Search and Rescue of Thua Thien Hue Province*	WARNING: Over the next 24-48 hours: Hot and extremely hot weather will continue to occur widely in Thua Thien Hue province, with some areas experiencing particularly extreme heat. The highest temperatures during this period will be 38.0-40.0°C (100.4-104.0°F) in the plains, midlands, coastal areas, and Hue city; 38.0-40.0°C (100.4-104.0°F) in Nam Dong district; and 35.0-37.0°C (95.0-98.6°F) in A Luoi district. The lowest humidity will be 35-50%. From April 5-7: Hot and extremely hot weather will continue to occur widely, with some days experiencing particularly extreme heat. From April 9: Temperatures will have a tendency to decrease gradually.