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RESEARCH ARTICLE

Climate change adaption strategies in urban communities: new evidence from Islamabad, Pakistan

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Abstract

Pakistan is urbanizing at the fastest pace in South Asia, and if left unplanned, it will not only reduce adaptive capacity of its residents rather it will be a chaos for its residents. The aim of this study is to answer the question on how urbanites of Pakistan are coping with climate change and which part of the society required support to cope with changing climate? To answer this questions, this study conducted survey through a structured questionnaire, from the urban residents of Islamabad, to explore their coping mechanisms towards climate change. Survey collected information on demographic, social, economic, and physical aspects, using Hackman's Treatment effect model. The sample selection equation is conditional on the adaptations to climate change in the outcome equation. Main independent variables are income, age, education, and occupation. Selection equation is based on perceptions of individuals about climate change which contains dependent variables of changes in temperature of summers and winters, changes in rain fall pattern, fog, hailstorm, and information received from social media and peer groups. With the result of 57.55, the Wald test shows that overall, there exists goodness of fit at the 99 percent confidence level. The value of *rho* in the Heckman model is 0.40 which implies the Heckman model provides more consistent and more efficient estimates. The results are suggesting that increasing age enhances the likelihood of adaptations as the positive and significant coefficient of age implies that age has probability to adapt to climate change. The positive and significant coefficient of income, education, and occupation implies that urbanites have higher probability to adapt to climate change. Perception is the essential foundation of adaptation, and differences in perception can be transferred to the adapted strategies. Households that experience a greater variation in annual mean temperature are more likely to adopt any adaptation strategy to cope with climate change. Essentially, poverty encompasses the majority of the characteristics that reduce respondents' adaptation capacity and increase their susceptibility to climate change. The major contextual disparities were discovered across union councils in the form of financial, personal, social, physical, and natural capitals of families. Therefore, obligation is on government to offer greater support for individuals who are less affluent in terms of these assets. For this city, officials must offer subsidy schemes to less privileged and marginalized people of urban dwellers to enhance their adaptive capacity.

Keywords Urbanization · Adaptation strategies · Climate change · Institutional capacity · Land use · Heckman's treatment effect

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Introduction

The popular opinion throughout the world, as portrayed in the media, is that the climate is changing and the planet is becoming a riskier place over time (Brooks and Adger 2003; Adger et al. 2020). These impressions are partially a result of increased knowledge about global ecological change and partially based on individuals' indirect and direct observations of extreme climate occurrences as a portion of their perception-making process. As a result, the need for adaptation may be the highest in locations, regions, and segments of society which is already at the limit of their ability to cope (Rehman et al.2022; Alvarado et al. 2022; Burton and Kates 1986; Jones and Kammen 2011; Smit et al. 1999).

The population of Karachi, now at thirteen million, is predicted to climb to nineteen million by 2025, while the population of Lahore, currently at seven million, is expected to expand to ten million, making Pakistan's urbanization rate the fastest in South Asia (Kugelman 2014). Urbanization in Pakistan is mostly attributable to the country's overall population growth. The movement of people from rural areas to urban centers is another issue, and it has been prevalent in Pakistan for much of the country's history. Those in rural areas of Pakistan are finding it difficult to get water; thus, many people (especially farmers and fishermen) are moving to the metropolis in search of better economic opportunities. Still, others are doing so to escape the devastation of things like earthquakes and floods, or to take advantage of better medical care and educational possibilities. Nonetheless, despite these successes, metropolitan regions throughout Pakistan, whether they be large metropolis or dense rural areas, have significant shortcomings.

According to Haider et al. (2014), there is a wide range of issues, including inadequate housing, inconsistent rubbish pickup, traffic, criminal activity, and illness. This is why, according to Kugelman and Husain (2018), urban problems in Pakistan "have continued to expand" due to decades of policies, strategic plans, community engagement, and new urban-focused governmental agencies. Together with traditional cities, Pakistan's rapidly expanding urban fringes now account for about two-thirds of the country's total population (Haider et al. 2014). Having serious consequences for public health, urban pollution in Pakistan is a major problem. Nearly 23,000 fatalities a year are attributed to the high levels of outdoor air pollution generated in large part by a rise in exhaust-belching automobiles, many of which are powered by leaded gasoline (Kugelman and Husain 2018). The environmental dangers in urban regions are greater than those in rural ones.

In addition, 96% of urban Pakistan had access to drinking water supplies that were safe from environmental contaminants in 2010, as reported by the World Health Organization (WHO). Drinking water supplies are poor, sporadic, and of lower quality despite the high degree of coverage. In Pakistan, water-related illnesses account for 60% of all cases. Four to six percent of city dwellers do not have access to a toilet, and the percentage is growing (World Health Organization (WHO 2017)).

Raw sewage is sometimes spilled into rivers and the ocean since cities only have a rudimentary sewerage network. Although a sizable percentage of the urban population receives urban services, the quality of life in Pakistan's main metropolitan areas is severely lacking. There has been an enormous building and real estate boom in Pakistan during the last two decades, and many of the country's cities and towns are relatively recent developments. Despite official policies laying the groundwork for such growth, various kinds of private businesses (formal and informal as well as illegal) have been major forces behind this. Salman et al. (2018) estimate that annual growth in housing demand throughout the country averages 270,000 new dwellings. This equates to a national unmet requirement of between 6 and 8 million homes. The majority of this shortage of dwellings is concentrated in urban areas. Almost half of city dwellers call Katchi Abadis and other shantytowns home. These places do not have reliable utilities, governmental approvals (in the form of planning and construction permits), or a guarantee of ownership.

Garbage collection is available to just 5% of metropolitan residences (Sohoo et al. 2022). Waste often decays in the public spaces. Roadside trash, including rotting food, plastic bags, and other items, is a problem even in affluent communities. The major thoroughfares are always clogged with traffic. Without proper drainage, rain causes roadway flooding. Cities sometimes face water constraints, power outages, and gas shortages. To a large extent, public authorities enable the illegal trafficking of water, power, and gas stolen from public supply lines, income, and trade are the predominant factors (Shahzad et al. 2020). Pakistan's economic development has been hampered by a shortage of electricity because of the country's incorrect energy strategy throughout the preceding decades (Rehman et al. 2021). There is a thriving protection racket industry, and land mafias are prevalent. The public transportation system is run by private companies and is prohibitively costly, grossly insufficient, and fraught with danger. However, the unexpected consequences of global warming, water shortages, and energy crises make these urban difficulties seem insurmountable. Pakistan has little trouble coming up with national policies, but there is usually no legal framework or institutional determination to implement them. Numerous working groups, committees, consultants, etc. were set up in addition to the National

Human Settlements Policy (1984), the National Conservation Strategy (1988), the National Housing Policy (1986), and yet another National Housing Policy (2001) (Salman et al. 2018).

Cities in Columbia give lessons on how to improve urban livability in a developing economy, cities in Africa, Latin America, and Asia might help us think of ways to meet the growing need for public transportation in our own cities. Even while urban residents are more likely than their rural counterparts to get numerous illnesses (Ulucak et al. 2021), there is a lack of data on the dangers of city life, which may explain why health policy remains rurally centered (GOP 2021). Urban government is inefficient and corrupt, and politicians only care about themselves. City plans cannot be implemented since there is no provincial planning law. The land registry is still structured after the agricultural norms and procedures of the nineteenth century. Clan allegiances form the basis of the moral order, and neither public interest nor adherence to the law has taken hold. In general, socioorganizational institutions fail to meet the four requirements for success. In its 61 years of existence, the CDA has failed to link the revenue data from its land holdings with its city planning diagrams. The effects may be seen in the final products. In Islamabad, 50 mosques have been constructed on encroached territory and are thus unlawful. As Hull (2012) demonstrates, these schemes were foiled by Pakistan's land tenure and transfer system and political-administrative institutions. Cities and towns are becoming less desirable places to live due to several factors, including but not limited to a lack of funding, inefficient processes, antiquated regulations, ineffective decision-making, and a moral lag. We must begin with institutional transformation if we are to make any serious effort to solve urban problems in Pakistan. The quality of life in cities may be greatly improved by switching these priorities around and providing for people's most fundamental needs. It suggests controlling population expansion by constructing low- to moderate-energy-consumption, low-travel-need neighborhoods (Rehman et al. 2022). In order to improve the health of communities as a whole, it is important to promote policies that have a less effect on the environment, use less energy, and have a smaller carbon footprint. Envision a community that has its own neighborhood board, schools, parks, and low-rise but high-density housing, as well as roads and roadways that have bike lanes and walkways running parallel to them. In order for urbanization in Pakistan to succeed, demand management is essential (United Nations, Department of Economic and Social Affairs 2018). Urban regions provide over 78% of Pakistan's GDP. Without a question, urbanization also fosters inequities, creates social conflict, and endangers environmental sustainability. However, it is a tool of progress, and growth, stability, justice, social progress, and environmental protection all depend on its proper management.

The effects of global warming on urban life in Pakistan's planned and uncontrolled regions are quite different. Private housing societies like Defense Housing Authorities (DHA), Bahria Housing, and navel anchorage around all of Pakistan's major cities not only provide residence but are also relatively free of environmental hazards as a result of individual decisions regarding adaptation to local conditions. A lack of information hinders research on urbanization (Kugelman 2014). In Pakistan, there is a dearth of academic inquiry into urban concerns generally and in the context of cities and climate change specifically.

Individuals, groups, and organizations may take coordinated collective action or operate independently to make various kinds of adaptations in response (Laukkonen et al. 2009). The government may choose to take part in making the necessary adjustments, or it can step back and let private sector efforts take the lead. The available data shows that relative performance varies from instance to case based on factors such as geographic location, community characteristics, and economic sector (Ludena and Yoon 2015; Ozturk and Al-Mulali 2015).

So, this research pose a question: how far people living in planned urban areas of Islamabad and nearby housing societies (housing societies by public and private enterprise in Pakistan) have succeeded in adaptation to the hazardous effects of climate change?

Research gap

Cities have a critical role in minimizing the consequences of climate change; thus, adaptation activities must be prioritized. Urban locations are high-risk hotspots due to their dense populations and infrastructures, importance to larger economic, political, and social processes, and intrinsic instability and vulnerability. There is a dramatic increase in the number of urban areas and human settlements that adopt and execute integrated policies and programs to promote social cohesion, resource efficiency, climate change mitigation and adaptation, and catastrophe resilience (Birkmann et al. 2010; Frantzeskaki et al. 2019; Valencia et al. 2019). Since climate change tends to harm urban areas by increasing the frequency and intensity of natural catastrophes and severe weather events, climate-resilient cities have many characteristics with other resilient cities. People, communities, and institutions become acclimated to risk, and catastrophe recovery methods are standardized in resilient cities despite the physical risk reduction (Lee and Kim 2018; Desouza and Flanery 2013; Wamsler et al. 2013).

Cities are crucial in the fight against global warming. Many responses to climate change have emerged outside the formal decision-making environment and have been led by actors other than municipal governments (Castán Broto and

Bulkeley 2013; Mitchell et al. 2021; Reckien et al. 2018), but the research on coping strategies of different segments of city life has been largely ignored in previous studies (Shahzad et al. 2021). In addition, the majority of the literature on climate change adaptation and mitigation to date has been on case studies of activities in advanced countries (Termeer et al. 2017; Ulucak and Danish Ozcan 2020; Rehman et al. 2020). Communities in underdeveloped nations have been ignored in previous studies of adaption options and tactics (Kazak 2018; Khosla and Bhardwaj 2019; Sharifi 2020).

By far in subcontinent, Pakistan is the fifth most populated country in the world and has the second highest population and has also one of the highest growing rates. This will continuously serve as a driver for land conversion from natural state to build environment. Pakistan is urbanizing at the fastest rate in South-Asia, and land conversion effects have been observed and lately increasing significantly at the expense of natural cover. It is unclear how these interacting changes in land use will force climate to change especially in the urban environment of Pakistan and thus the living conditions of city inhabitants. Such kinds of analysis that support better understanding of the climate-urban interactions and the resulting adaptation strategies adopted by different segments of city inhabitants to climate change in Pakistan are rare, which is due to limited availability to primary data. However, where such studies exist, they either work on secondary data taken from PSLM, HIES, and WDI which are relevant for country and regional level studies, while the local level studies need to rely on primary data as each part of the society comes across with its own issues and hazards and seldom implement rigorous data standardization and validation strategies. Further, the local level studies rely on primary data; this in turn raises question on reliability of existing investigations.

Based on these gaps, especially at local scale, inventories of urban environments remain challenging and relevant to researcher, policy, and decision makers for improved understanding of human well-being and security in urban areas will respond to climate variability. This research addresses relevant research question that empirically closes the knowledge gap about data issues, methodologies, and scientific explanations about climate change within the urban climate science framework. As a result, the scientific community and the continuing talks under the Convention are both likely to pay greater attention to adaptation as its relevance grows (Feenstra et al. 1998). So, this research addressed the issue of understanding the strategies individuals took to cope with the climate change in densely populated urban developing country like Pakistan. Based on such understanding of coping mechanisms, this research suggested authorities and policy makers to support those parts of society, whose capacity to cope with climate change is weak.

Methodology

In the context of climate change, the phrase "adaptation" may refer to a variety of different things. If people come to accept that climate change is happening and is already having an effect on their lives, they may be more open to changing their behavior to accommodate the new normal. Because people's perceptions of climate change and their corresponding adaptation strategies may be influenced by their socioeconomic status, social interactions, and information exposure and source effects, it is not sufficient to focus on mitigation or adaptation alone; rather, a combination of the two produces the most sustainable outcomes. Unfortunately, there are times when the two approaches are not just ineffective, but actively harmful. That is why it is important to have a system and a comparison tool to figure out which solutions are going to be the most beneficial and affordable for various communities. Negative effects of potential strategies must be weighed, and those with the fewest should be prioritized (Laukkonen et al. 2009).

The research was motivated by the Intergovernmental Panel on Climate Change (IPCC) emphasis on adaptation, which is defined as "changes in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploit beneficial opportunities" (Intergovernmental Panel on Climate Change 2014). Using Exploratory Data Analysis (EDA) and Hackman's Treatment Effect model, Javed et al. (2015) found evidence that people's views on climate change and their resulting adaptation strategies differ by gender and other demographics. These factors, along with others such as housing affordability, zoning restrictions, traffic, and air pollution, all play a role in whether or not people choose to settle in a given area. The level to which a system will automatically make adjustments at any particular time is defined as adaptation, which depends on the following factors:

- Realization about the need for adaptation
- Beliefs that adaptation is viable and necessary
- Willingness to adapt
- Availability of resources required to implement adaptation methods
- Ability to deploy resources effectively

The execution of adaption techniques is hampered by external restrictions or impediments.

Description of the study area

Islamabad is a capital city of Pakistan. Islamabad is a metropolitan area that exists in north of central Pakistan.

Islamabad is at the ninth position according to the population in Pakistan. It is a planned city-built structure in the 1960s as Pakistan's capital, Islamabad with a population of 1.7 million, with lofty standards of living, large roads, safety, well-built sewage and sanitation system, and abundant greenery. The area of Islamabad city is 220 km^2 with a population of 1.2 million. Zone-I and Zone-II are encompassing the urban union councils of Islamabad given in the map below. Figure 1 is demonstrating the location of the study.

Model specification

It is possible to classify adaptive behaviors as anticipatory, autonomous, or intentional, and adaptation occurs when natural or human systems change in response to present or predicted climatic stimuli or their consequences to reduce negative impacts or maximize positive ones (Intergovernmental Panel on Climate Change 2014). Indicators of resilience and adaptability may be developed via either top-down or bottom-up processes (GC and Yeo 2020; Tyler et al. 2016).

Expert-created metrics are more likely to include extensive data, novel theoretical models, and surprising analytical findings. It is possible that community or user-driven metrics lack rigor, but they are more likely to produce power, deliver outcomes with better local value, assure dedication and mastery of findings, etc. (GC and Yeo 2020; Reed et al. 2007). The selection of indicators is fundamentally subjective, even when using expert-driven methods (Eriksen and Kelly 2007; Huang et al. 2018). There are two phases of adapting to climate change. The first stage in adapting to a changing environment is being aware of the changes that are occurring and then selecting whether or not to implement an adaptation plan. When making assumptions about the population as a whole, it is problematic to include just those who consider they can acclimate to climate change. This suggests that the treatment effect model might be used to deal with the problem of selection bias. The model of adaptations based on perceptions of the urban residents is illustrating in Fig. 2. Further, Fig. 3 is demonstrating the adaptation strategies taken by urban residents.

Selection equation

There are two equations in the Heckman model, one for the selection process that captures the selection bias and the other for the result process that represents the specification of interest. In the selection equation, perception is used as a dependent variable. The Probit model for sample selection equation, like the Heckman model, is estimated to include unobservable factors. The inverse Mills ratio (λ) is used to detect selection bias, and it automatically enters as

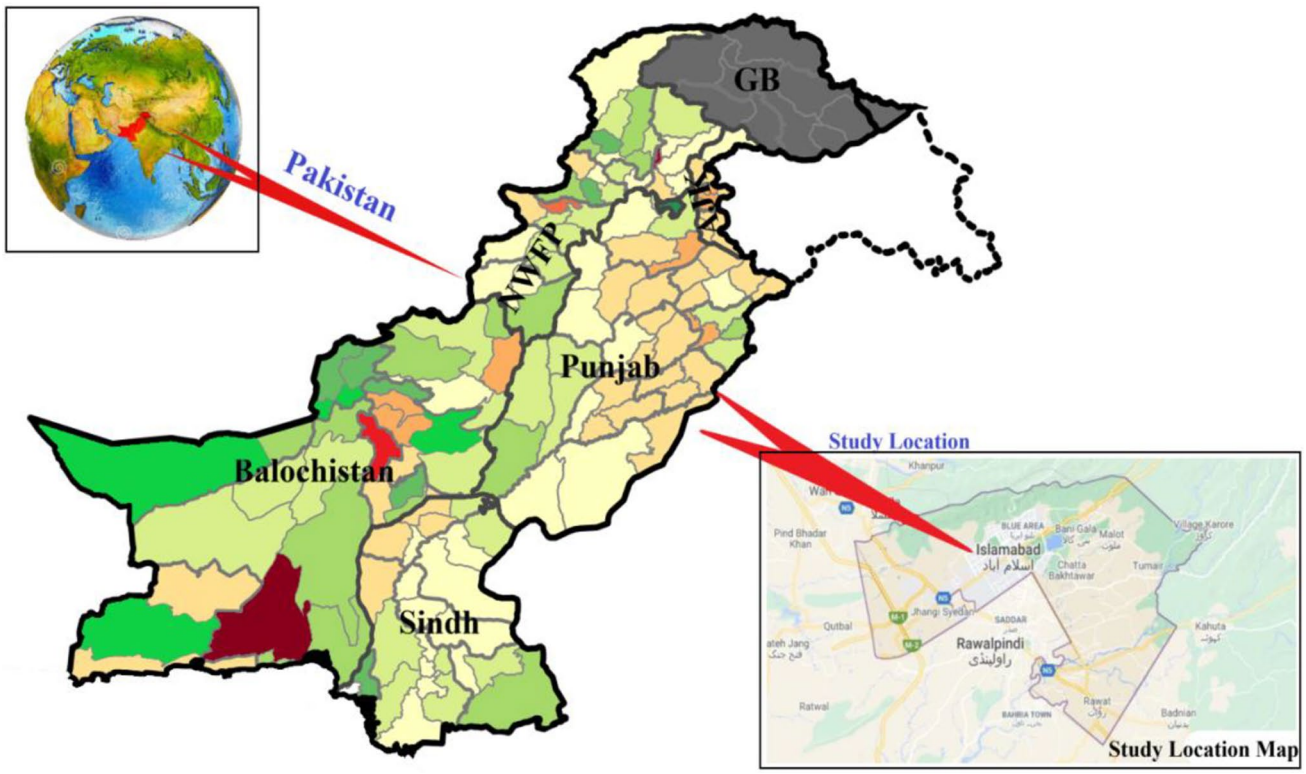

Fig. 1 Study location (Islamabad, Pakistan)

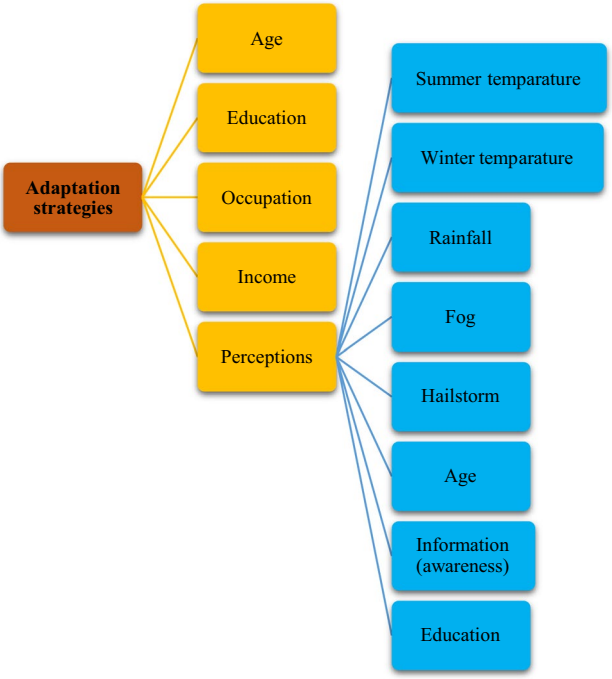

Fig. 2 Model of adaptations based on perceptions of the urban residents

an independent variable in the result equation. The treatment effect model avoids the necessity for the Heckman approach, which is a major benefit. Furthermore, both treatment effect amplitude and selection bias are included in the treatment effect model. The equation for selecting samples may be expressed as follows:

$$d_i = x_i\alpha + \mu_i \tag{1}$$

where $d_i > 0$ and 0 otherwise

$$\text{Prob}\left(d_i = 1 \middle| x_i\right) = \phi(x_i\alpha) \tag{2}$$

and

$$\text{Prob}\left(d_i = 0 \middle| x_i\right) = 1 - \phi(x_i\alpha) \tag{3}$$

Households who notice changes are assigned the value 1 (perceived = 1); otherwise, zero and d_i could be estimated when $d_i = 1$ if $d_i > 0$ and for $d_i = 0$ otherwise.

We may understand this in terms of the perception-based conditionality of adaptation. Explanatory variables (represented by x_i) include the following: education, age of head of household, rainfall, fog, hailstorm, information, and summer and winter temperature. There were primarily five groups of jobs identified, ranging from being self-employed (as 1) to working for the government (as 5). In addition, μ_i stands for an error term, and α is a vector of coefficients. The assessment job involves making

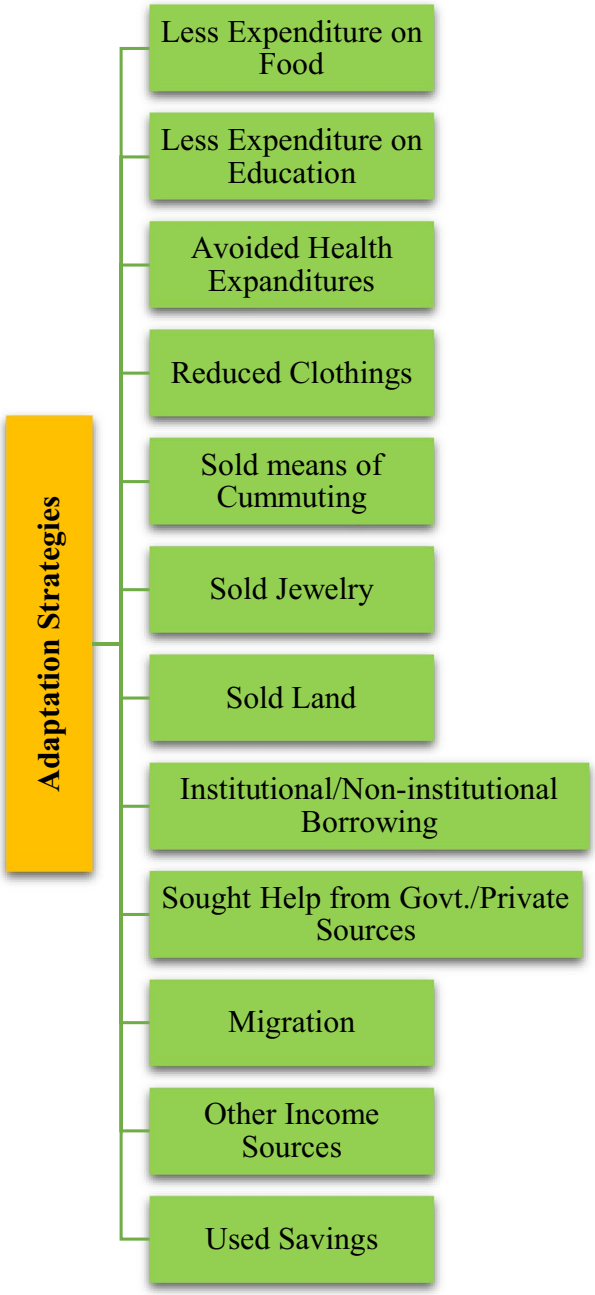

Fig. 3 Adaptation strategies taken by urban residents

an estimate of the regression coefficient (β) based on the observed variables, with consideration given to selection bias and the fact that "d" is an endogenous variable. To quantify the selection bias issue, one might use the Lambda or reverse cutter ratio, which is defined as

$$\lambda = \phi\left(x_i / 1 - \phi\left(x_i\alpha\right)\right) \tag{4}$$

It is important to note that in this context, ϕ represents a normal distribution and is a density function.

Outcome equation demonstration

The outcome equation with variables of interest or policy relevant as a dependent variable are given here as

$$z_i = y_i\beta + d\alpha + \varepsilon_i \tag{5}$$

where z_i is a climatic adaption variable, y_i is a vector of explanatory variables such head of household age, education level, etc., a set of parameters, and d is a perceived dummy variable produced directly from the selection equation (called the treatment effect), and the resultant equation is useful because it allows you to see how different things would be if you compared treated families to those who were not. The resultant equation has an error term expressed as ε_i.

The key independent variables comprise household features along with institutional factors such as information, which impact adaptation behavior and the selection of certain adaptation techniques. Age, education, employment of head of home, temperature, rain fall pattern, fog, and precipitation were all chosen based on prior research. In this way, dependent variables can be perception and relevant adaptation (GC and Yeo 2020). In the selection equation, factors such as urban dwellers' social networks and socioeconomic status impact how they interpret climate change. These are the components of the Likert scale:

Adaptation = number of plans adopted by a resident/total number of plans

Household traits and institutional factors like information are the most important independent variables, as they influence adaption behavior and strategy selection. Age, education, government extensions, temperature, and precipitation were among the factors chosen based on prior studies. Perception and adaptability serve as the dependent variables. Different families and socioeconomic characteristics that influence urbanites' climate change awareness are among the explanatory variables for selection.

Study data

The data for this study was collected using the household survey (HHS) one-shot approach. A team of enumerators along with principal investigator accessed heads of household in each union council of Islamabad. In the case of unavailability of heads of household, the members of a household were approached. Enumerators explained the reason and each question of the survey. The questionnaire offered by this study is self-administered in nature and was distributed to the urban respondents. The participants were given a full explanation of the study's goals, potential advantages, potential drawbacks, and funding sources before they were asked to fill out any questionnaires. Respondents were guided to fill out the questionnaire and where respondents had any issue they were explained. In case there was any illiterate who could not understand language, the research team filled out the questionnaire on behalf of the respondents with the consent and approval of respondents. Given that 20 respondents were to be selected from each union council in Islamabad, questionnaires were split up as follows: five were given to residents living on the right hand side of the sector, five were given to residents living on the left hand side of the sector, five were given to residents living on the front of the sector, and five were given to residents living on the back of the sector, all at the Markaz (the middle point of each union council). For example, in the F-6 sector of Islamabad, five questionnaires were distributed in F-6/1, five questionnaires were distributed in F-6/2, five questionnaires were distributed in F-6/3, and five questionnaires were distributed in F-6/4. It can be visualized as in Fig. 4:

Sample size

The minimum effective achieved sample size was 440 households after discounting for design effects, distributing 385 households. To achieve good representative sample, population proportion to the size from the target population has been adopted by collecting twenty questionnaires from each urban union council of Islamabad. As a result, the sample size was calculated using the following formula, which took into account the size of the population:

$$n = [(N)(p)(1-p)]/[(N-1)(B/C)^2 + (p)(1-p)] \tag{6}$$

where n is the calculated sample size needed for the desired level of precision; N is the size of the population; p is the percentage of the population expected to choose; B is the acceptable amount of sampling error or precision; and C is the Z statistic associated with the confidence level, which is 1.96, corresponding to a 95% level of confidence. Error or precision in the sample is allowed to be no more than 5%, or 0.05. A 95% certainty is reached with a confidence level of 1.96. In order to have a bigger sample size, choose a significance level of 0.05. But whether the population is tiny or huge, the sample size it provides is always sufficient.

Here, $N=2$ million, $p=0.5$, $B=0.05$, $C=1.96$,

$$n = [(2{,}000{,}000)(0.5)(1-0.5)]/[(2{,}000{,}000-1)(0.05/1.96)^2 + (0.5)(1-0.5)] \tag{7}$$

$$n = [(2,000,000)(0.5)(0.5)]/[(2,000,000)(0.0255)^2 + (0.5)(0.5)]$$
$$n = 384 \tag{8}$$

A sample of 440 responders was finally picked for multiple variables, which was 16 percent more than the

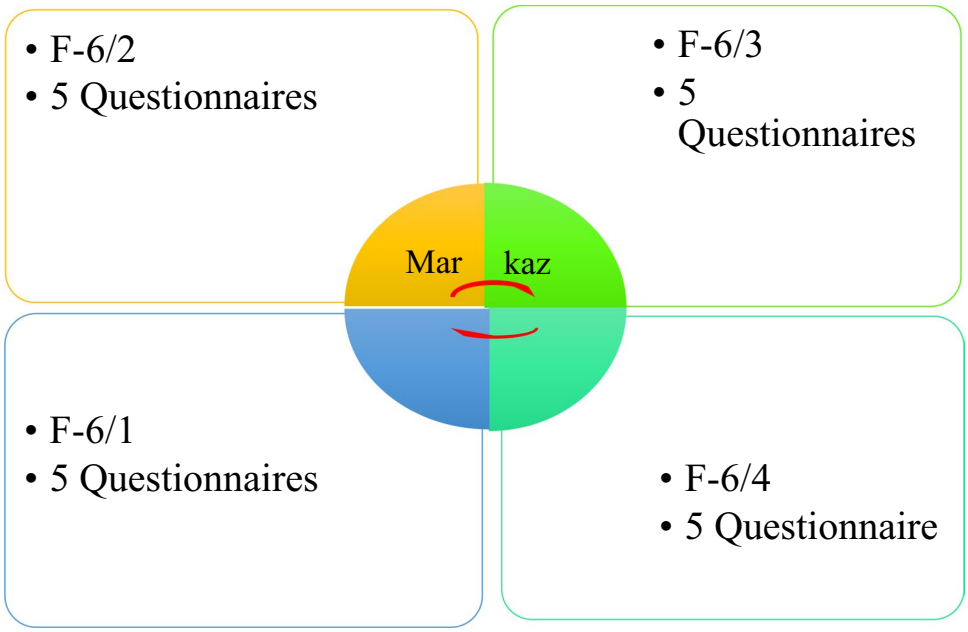

Fig. 4 Sample questionnaire administration

needed sample. For instance, having a bigger sample size increased confidence that sample responses do not differ considerably from real opinions. Oversampling helped guarantee that the required sample size of 385 people was met. Furthermore, the large sample size helped in ensuring adequate stratification according to the regressors chosen. Finally, a greater sample size improved the generalizability of the study's findings.

Study results and discussion

Urbanites of Islamabad have perceived changes in temperature of summers and winters as well changes in rain fall pattern according to the information they received from social media and peer groups. Research in these areas is necessary because, to be effective, climate change policy must dissect each of these components separately.

Descriptive statistics of sample respondents of Islamabad

During the survey, the mean age of the respondents in different union councils of Islamabad was found to be 47 years with a minimum of 21 years and a maximum of 75 years shown in Table 1. The highest education was found to be eighteen years, out of these while 8% were illiterate, 25% of the respondents had primary level education, and 20% were matriculate and the remaining 47% had higher qualification. The mean household size was about six persons per HH with a minimum of two persons and a maximum of nine persons per HH. About 52% were male, and the remaining 48% were female respondents; out of this, 52% were married and 48% were single. The maximum monthly income of the respondents was found to be PKR 270,000, and the mean income was 57,000 which are well above the per-capita income of Pakistan which is PKR 17,000. It can be associated with the

Table 1 Descriptive statistics of respondents of Islamabad

	N	Range	Min	Max	Mean	Std. deviation
Age (years)	390	54.00	21.00	75.00	47.90	10.92
Education (schooling years)	390	18.00	0.00	18.00	13.09	2.95
Monthly Income (Pak Rs.)	390	160,000	10,000	270,000	57,019	24,459
No. of children	390	6.00	0.00	6.00	2.81	1.32
Number of HH members	390	7.00	2.00	9.00	5.61	1.54
Mean age of HH	390	40.00	25.00	65.00	46.97	9.06
HH aged over 65	390	5.00	0.00	5.00	2.90	1.12
HH aged below 15	390	6.00	0.00	6.00	3.13	1.09
Highest education of HH	390	11.00	8.00	18.00	13.35	2.06

Source: authors' own calculation.

fact that Islamabad is the capital city of Pakistan, and rich people prefer to live in here.

Based on such perceptions, urbanites of Islamabad must have taken relevant adaptation strategies. A set of adaptation strategies along with percentage of individual strategy taken by the urbanites of Islamabad is given in Table 2.

Using Hackman's Treatment effect model, an adaptation study of Islamabad city dwellers is provided to determine the drivers of adaption methods. The result equation includes the effects of climate change, and the sample selection equation depends on those effects. By dividing the number of adaptation techniques, a person has adopted by the total number of strategies; we get the dependent variable adaption, which is then used in the outcome equation. Main independent variables chosen from previous studies are income, age, education, and occupation. Selection equation is based on perceptions of individuals about climate change which contains dependent variables of changes in temperature of summers and winters, changes in rain fall pattern, fog, hailstorm, and information received from social media and peer groups.

In Table 3, with the result of 57.55, the Wald test shows that overall, there exists goodness of fit for this model (Wairimu Ng'ang'a and Crane 2020). At the 99 percent confidence level, this means that the two models reject the equation's independence. From the sample of 390, it is observed that thirty-eight respondents, who are censored, did not at all perceived changes in climate like variation in summer and winter temperatures or rainfall patterns while 352 respondents not only perceived changes in climate rather adopted at least one adaptation strategy.

The presence of selection bias is shown by the inverse Mills ratio's significance in the model. The value of *rho* in Heckman model is 0.40 which implies the Heckman model delivers more dependable and more effectual approximations for given set of parameters (Batool et al. 2018; Esfandiari et al. 2020). Also, this study found some evidence that if *rho* does not equal to zero (which is 0.40 for this study) this alone makes it possible to conclude the presence of a selection bias. Consistent with Kazak's results, it has been observed that people's discernments of climate change are prejudiced by the information they get from the media, social networks, and personal observation on temperature, rainfall, and hailstorms (Kazak 2018). The findings revealed that all the explanatory variables are significantly affecting the adaptation.

Table 2 Adaptation measures taken by urbanites of Islamabad

S. No	Strategies	Percentage of urbanites who adapted strategy
1	Reduced expenditures on clothing	67.18
2	Less expenditures on Education	19.74
3	Reduced expenditures on health	30.51
4	Sold transport	28.72
5	Sold jewelry	56.41
6	Institutional borrowing	69.74
7	Non-institutional borrowing	43.85
8	Sought help from government	66.67
9	Sought help from private sources	52.82
10	Migrated	58.21

Table 3 Outcomes of Heckman's treatment effect model for Islamabad

Adaptation	Outcome Eq			Selection Eq		
	Coef	*Z*	*P* > *z*	Coef	*Z*	*P* > *z*
Age	0.19	5.81	0.000***	−0.0187	3.55	0.000***
Education	2.01	2.33	0.020**	0.112	4.92	0.000***
Occupation	1.11	3.14	0.002***			
Income	0.0035	2.02	0.087*			
Cons	10.122	4.90	0.000			
Perception	0.185	3.76	0.000***			
Summer				2.248	8.46	0.000***
Winter				1.503	6.36	0.000***
Rainfall				0.505	1.97	0.049*
Fog				0.025	0.09	0.926
Hailstorm				−0.199	−0.71	0.479
Information				1.46	6.41	0.000***
Inverse Mills ratio lambda	2.11	1.37	0.072*	Rho	0.40	
				Sigma	5.24	

Number of observations = 390, Wald chi^2 (4) = 57.55, Prob > chi^2 = 0.0000, censored observations = 38, and uncensored observations = 352.

***, **, and * expose the level of significance at 1%, 5%, and 10% level, correspondingly.

The consequences in Table 3 are suggesting that accumulative age enhances the likelihood of adaptations as the positive and significant coefficient of age implies that aged head of household and family members have higher probability to adapt to climate change (GC and Yeo 2020). This can be due to many factors such as aged heads of household which are more vulnerable to higher variations in temperatures and increased rainfall as well as having perception towards, intensity, and frequency of summer and winters. If these aged people are part of household only but have significant contribution towards decision-making by the head of household, then more resources of the household would turn towards adaptations.

It is also suggesting that higher education increases the awareness of household towards changing climate thereby increasing the likelihood of adaptation (Rousell and Cutter-Mackenzie-Knowles 2020). Due to the positive and statistically significant coefficient of education, we may infer that more educated households will be better able to adapt to climate change than less educated ones. It is observed that education played a vital role in determining urbanites of Islamabad to adapt to climate change. The lower costs (in monetary terms) of implementing such adaption measures may also influence the decision to use such solutions. These results are in line with the study by Javed et al. (2015), allowing the enhancement by urbanites' adaptive capacity.

Occupation of the respondents is positively and suggestively related with adaptations made by the heads of households. Mainly five occupation categories were identified, from self-employed (as 1) to government employed (as 5). It is a well-known fact in Pakistan that government employees have less uncertainty of loss of job and income as compared to private jobs, so the results showed direct and significant relation of adaptation to climate change and occupation which is in line with the findings of Barrows (1935), but it cannot be mixed with occupational exposure of the healthcare providers Yarahmadi et al. (2021), as these professionals are more vulnerable to health hazards. Table 3 shows that if a person lives in a city and makes a lot of money, they are more likely to be able to adapt because they have the resources to do so. If one perceives changes in climate, he/she can take such adaptation measures which they can afford (Ullah 2016). It is possible that city people are more ecologically sensitive and, as a result, more motivated to adapt in order to retain their current way of life.

Perception is the essential foundation of adaptation, and differences in perception can be transferred to the adapted strategies to be taken. Coefficient of age is negative and significant which is in line with the findings of Batool et al. (2018), Esfandiari et al. (2020) and Javed et al. (2015) implying that increasing age would not be positively influencing the perceptions of the respondent. Coefficient of education is constructive and substantial implying that increasing education would improve the perceptions of the urbanites of Islamabad which is evident from previous research (GC and Yeo 2020; Hurtado 2014; Khan 2003). The examination of adaptation strategies demonstrates that people who perceive that climate change is occurring and impacting their lives would opt for more adaptation strategies available to them. Our main concern is to discuss the factors influencing the adaptation strategies of the city dwellers in Pakistan. Adaptations to climate change in the outcome equation are conditional upon the sample selection equation. In this model, the dependent variable is adaptation to climate change which is generated by using the Likert scale that takes into account all the strategies adopted. Constructing the dummy of adaptation variable gives equal weights irrespective of the number of adaptation strategies undertaken. It is a revealing fact that multiple adaptation strategies adopted simultaneously may have different impact than that originated by any single adaptation strategy.

When asked if they would have just used any adaptation strategies to respond to perceived climate change, majority of the respondents said they had used at least one adaptation strategy, while the remaining said they had not. The findings here are consistent with those of GC and Yeo (2020), Haunschild et al. (2016) and Maller and Strengers (2011).

Households that experience a greater variation in annual mean temperature are more likely to adopt any adaptation strategy to cope with climate change. Urban inhabitants are expected to develop additional techniques to cope with rising temperatures as the result of global warming. This variable has a positive and significant coefficient. Changes in rainfall patterns also influenced the perceptions of the sample respondents which are resulted in adoption of adaptation strategies. The outcomes are in the consistent with findings of Deressa et al. (2011), and Charles et al. (2014).

Many forecasts have documented that urban growth is inevitable due to population growth and will dramatically drive the Global Environmental Change such as Land Use and Land Cover Change (LULCC) and climate change. Unfortunately, causes and effect of the changing climate are not entirely understood, not only at the global scale but also at regional and local scales. South-Asia, especially subcontinent, has been identified as one of the severely threatened regions of the world. The knowledge about the impacts of the changing climate regime is also poorly understood in subcontinent. Thus, avoiding the negative impacts and anticipating potential positive gains for sustainable human living conditions are challenged. Significant population growth trends aggravate the challenge further, especially in regions experiencing rapid urbanization.

Conclusion

Broadly defining, the following two aspects are examined through this research: first, the study sought to demonstrate the level of adaptation capability of Pakistani city inhabitants; second, it sought to measure the impact of household-specific adaptation strategies taken and adaptive capacity variables in influencing susceptibility to climate change. The analysis of settlement expansion and urban growth modeling for evaluating potential influences of climate change on city dwellers in twin cities is the first analysis investigated in detail. Understanding the spatial and temporal distribution of urban heat island impacts in Islamabad required a combination of indicators and statistical methods. Adaptation studies demonstrated that green space might mitigate the urban heat island impact.

The increasing air and surface temperature is resulting of the rapidly changing land cover with impervious surfaces, particularly the built environment. The prevalence of family members with protracted sickness, as well as the increased sensitivity of families to climate change, all contributes to households' limited adaptive capacity and fragility. However, a high level of adaptation results from the accumulation of valuable assets enhanced social and institutional links and a deeper awareness of climate change.

Essentially, poverty encompasses the majority of the characteristics that reduce respondents' adaptation capacity and increase their susceptibility to climate change. Human capital issues, such as long-term disease and a lack of education, are prevalent in the studied region. Household health and the presence of nonworking members have a significant detrimental impact on the poor and disadvantaged groups' limited resources. In addition, there is an alarmingly low level of social capital present in such Pakistani urban areas, as measured by participation in social groups and networks.

Households with higher adaptive capacity are more likely to employ adaptation techniques in the face of harsh weather and shock conditions, which aid in avoiding or mitigating the negative effects of climate change. For having improved access to evidence, availability of clean water through filtration plants, provision of extension services, and adequate access to credit from institutional as well as noninstitutional sources along with sources of help sought from institutional as well as noninstitutional sources in emergency also had an influence of higher adaptive capacity. Family, friends, and neighbors are important sources of information about climate change, and social contacts in an emergency increase the likelihood of adaptation, either individually or in combination. The ability of city dwellers to mitigate the negative effect is mainly reliant on the availability of resources.

Implications

Significant contextual disparities were found in the financial, human, social, physical, and natural capital of families among trade union councils. So, it falls on the government to help others who are less in need in this area to make up the difference. Because poor households have less means to adapt to climate change, access to the financial sector is critical for them to convert their livelihood and settlement into a cleaner and greener environment with affordable housing. Adequate finance availability helps them to overcome fundamental challenges to climate change adaptation. For this reason, this study has specific recommendations as follows:

Local vulnerability and adaptive capacity analysis should be done for each city to get better idea that which part of the society is in need of special attention. It will also allow identification of vulnerable zones for buildings. Waste collection should not only be provided in posh areas of city dwellers rather it should be for all residents including *kachi basti* in the peripheries of the cities and waste segregation can be introduced through the provision of two or more waste bins in front of each house or street and recycling plants can be offered in each city through public private partnership. Water and sanitation services should also be provided to these vulnerable parts of the society. Experiences and help can be sought from public private ventures in this regard. Energy-mix in Pakistan is not favorable for clean and green environment, but the government can provide subsidy on solar panels and provide it to the most vulnerable parts of these societies at lower price, which will not only be environmentally friendly but also it will lessen the energy costs of the poor and marginalized people. In the present study, significantly higher electricity consumption was reported from areas with high population density. Improve social and economic benefits for everyone without compromising the health of vital ecosystems by integrating water resource management in a way that promotes planned development of water systems, land, and related resources. The concentration of traffic around city centers results in pollution and poor urban air quality. Cheap and environment friendly transportation in cities should be the topmost priority of the local and national governing bodies. For this, mass-transit authorities of each city should further enhance routs of metro busses and trains throughout the city. Single vehicle commuters of rich class can be brought into the metro-busses and trains by offering segregation in this mass-transit system in the form of business class where higher fares can be charged, and this will allow the authorities to offer even lower fares for the economy class commuters. The current government of Pakistan is ambitious in offering affordable five million housing units to the masses of urban population with the name of "Naya Pakistan Housing Scheme" under the Naya

Pakistan Housing and Development Authority. This mass construction project should also encompass the aspect of environment by means mass-transit, green infrastructure, and energy efficiency for sustainable livelihood.

Health facilities are available in city centers, but they do not serve the majority of the people; hence, dispensaries at the union council level are advised, with the emphasis that the wealthy can afford private health care, but the poor cannot. People living in densely populated areas of most of cities of Pakistan, face elevated temperatures, which reduces their productivity due to health losses and number of bedridden days. As a result, health services for the poor and disadvantaged should be offered at their doorsteps. The abovementioned initiatives must be monitored and evaluated.

Future research direction

This research encountered scarcity of suitable land use land cover, settlement expansion analysis, and urban growth for mapping, monitoring, and modeling vulnerability and adaptive capacity especially through satellite imaging of settlement expansion analysis. Yet the research does provide a basis for further urban vulnerability analysis towards urban climate science. The principal areas for future work directly relevant to this research are as follows:

Further investigation of land use land cover, settlement expansion analysis, and urban growth modeling using dense satellite dataset and satellite imaging, to capture decadal and seasonal timeframes, is needed. To gain better understanding of heat island effect and global warming, temperature and humidity readings of different union councils should be considered in future research. This can also be used for other global temperature and rainfall analysis within the context of urbanization and climate change impacts. Due to time and monetary constraints, this study analyzed strategies to adapt to climate change analysis of Islamabad only. Results from this study cannot be extrapolated to the entire urban population of Pakistan due to the fact that people in different cities face different types of hazards and risks. However, more research into local adaptive capacity for the entire country would enrich the assessment of localized analysis.

Limitations of the study

Access to sufficient secondary datasets such as historic climatic data at union council level was a challenge, and it did not allow this study to include exposure analysis of vulnerability to climate change. In addition, Islamabad had only one climate station situated near Noor Khan Airport which hampered spatial reliability assessment of the land surface temperature. Temporal population and socioeconomic datasets were not available at union council level which could have supported detailed estimates of vulnerable population to historical potential climate change impacts. Time and monetary constraints did not allow this study to analyze the universe of the urban population of Pakistan.

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Declarations

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