Examining climate change awareness and climate-friendly activities of urban residents: A case study in Košice

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Abstract: *As the impact of climate change begins to be felt all around the world, the vulnerability of urban areas due to their population density, high concentration of economic activities and the altered characteristics of the physical environment is becoming increasingly apparent. As a result, cities will play a crucial role in tackling climate change by fostering mitigation activities and managing and coordinating the adaptation process. Research has shown that engagement and awareness among citizens is vital in the promotion of effective adaptation policies, but studies have also drawn attention to the significance of the so-called "awareness-action gap," the absence of a direct link between awareness and action. This study contributes to the ongoing debate over the awareness-action nexus by discussing the factors that can affect the adaptation and mitigation activities of urban citizens using the Slovak city of Košice as a case study. Data was collected using a survey conducted with local residents as part of the preparations for the city's first adaptation strategy on climate change. The paper uses a two-step analysis to investigate the socio-economic, psychological and contextual factors associated with climate change awareness and climate-friendly activities. The results of the standard linear regression model indicate that self-assessed vulnerability is a determining factor in both the level of climate change awareness and the likelihood of individuals to take action. In the second step, we find that the factors which influence engagement in climate-friendly activities differ depending on the costs involved in implementing the activities. The exploratory analysis conducted using a machine learning algorithm suggests that the awareness-action nexus may be non-linear in nature. The main findings of this study imply that communication strategies should place a primary emphasis on individuals' vulnerability to the negative impacts of climate change. The paper contributes to the existing research by providing a case study of a generally under-researched geographical area of Central Europe. In addition, the analysis provides a specific context of urban area and implications for local policymakers, something that has been lacking the in literature looking primarily at data at the country level.*

Keywords: *Climate change awareness, citizen engagement, awareness-action gap, vulnerability, economic aspects of adaptation.*

JEL Classification: *R58, Q54.*

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Introduction

Cities and urban residents have a crucial role to play in the development of climate change mitigation and adaptation. There are estimates that 50% to 80% of the measures which are necessary to mitigate the impacts of climate change require regional and local implementation and also suggest that the decisions of local governments can potentially influence up to one-third of all urban greenhouse gas emissions (OECD, 2021). The necessary public support of climate change policies is affected by people's environmental beliefs (Kácha et al., 2022). As a result, cities should make efforts to systematically raise awareness and involve governance factors as a standard procedure in adaptation efforts (Tapia et al., 2017). In order to do so, local policymakers must be well informed about the preferences of residents, their motivation and engagement in climate-friendly activities.

The aim of this paper is to examine the factors affecting engagement in adaptation and mitigation activities among individuals in the urban environment. Although cities are considered among the key actors of climate action, the existing literature on climate change awareness and action has primarily examined the issue at the national level or among specific socio-economic groups (Valenzuela-Levi et al., 2022). Moreover, little attention has been paid to specifically urban topics, such as the impact of heatwaves (Lenzholzer et al., 2020), which will be the greatest climate-related issue in many European cities. Additionally, there is a distinct lack of studies which have investigated urban awareness of climate change within the specific geographical context of Central and Eastern Europe. Individual nations and population groups often hold idiosyncratic views on climate change (Kácha et al., 2022), and regions embedded in various socio-economic and cultural milieus could form differing associations to climate change (Poortinga et al., 2019). Our study thus contributes to the existing literature by providing a novel perspective on climate change awareness and engagement in a local urban context.

Our study focuses on climate change awareness among the population of the city of Košice in Slovakia. We chose this city due to the fact that Central Europe, and especially urban areas, were under-represented in the previous research. The context of the post-socialist city with historically low citizen engagement might offer valuable insights into why some areas are lagging behind with their adaptation efforts. In addition, Košice is a city with a prominent industrial heritage, which also indirectly influences peoples' views on green transformation and sustainable futures. Being in this specific situation, the mechanism of climate change awareness and citizen engagement in climate friendly action might take on some specific context-dependent form.

Our case study offers an analysis of climate change perceptions and the adaptation and mitigation activities of city residents, the findings of which could serve as a first step in developing an effective communication strategy between authorities and local citizens. In the paper, we address the following questions. What factors influence the awareness of urban residents regarding climate change? What factors influence local citizens' engagement in climate-friendly activities? What is the connection between awareness and action? Do the factors differ depending on the cost of implementing the activities?

The paper is organized as follows: Section 1 offers a general description of the context and a literature review discussing the factors which influence attitudes to climate change, followed by a description of the data and methodology in Section 2. Section 3 applies regression analysis and the random forests model to analyze the data and presents a discussion of the main findings of the research, while the final section concludes with possible policy implications.

1. Theoretical background

1.1 Factors affecting climate change awareness and climate-friendly activities

Levels of climate change awareness have been found to differ across countries, contexts and individuals. A review by Gifford and Nilsson (2014) and a meta-analysis by Hornsey et al. (2016) offer a comprehensive list of the relevant factors which determine climate change beliefs and attitudes. The most intuitive characteristics relevant to climate change perceptions are the more sociodemographic aspects such as gender, age and education. People who accept the reality of climate change are usually younger, more educated and from higher income brackets, with the categories of gender or

race having a less significant impact on awareness. Climate change awareness also differs across countries (Poortinga et al., 2019). While a belief that human activities are contributing to climate change is a predictor of risk perceptions in Latin America and Europe, in Asia and Africa, changes in temperature are seen as the most prominent (Lee et al., 2015). Even the effect of education is not uniform across countries or among different political affiliations of citizens (Czarnek et al., 2021). In more developed countries, the topic of climate change is seen as a more politicized topic, and in such a context, education alone might not be enough to raise awareness about the risks of climate change, especially among right-wing voters (ibid). Differences were also identified between European countries, with the effects of demographic and socio-political factors found to be less significant in Eastern European countries than in Western states (Poortinga et al., 2019).

In addition to the sociodemographic and country-specific contexts, other factors that could be classified as psychological have been identified. The levels of subjective knowledge of scientific findings concerning climate change were largely the same for both "believers" and "sceptics," but a higher level of objectively measured knowledge is connected to a stronger belief in the reality of climate change (Hornsey et al., 2016). Personal traits such as open-mindedness, conscientiousness and lower emotional stability were also found to be related to environmental concerns (Gifford & Nilsson, 2014). Moreover, a willingness to support climate-related policies also stems from individuals' attitudes towards long-term planning or attachment to place (Alló & Loureiro, 2014), with those expressing a stronger attachment to global rather than national identities being more likely aware of climate change and hold a positive view towards climate change responses (Devine-Wright et al., 2015).

In terms of the magnitude of the effects, the socio-economic and psychological characteristics were overshadowed by variables connected to values, beliefs, political affiliation, worldviews and culture (Hornsey et al., 2016). One of the most important factors is that of social identity (ibid); individuals who identified with a "green" or activist identity or who stated that they valued the natural environment were more likely to believe in the reality of climate change.

Theories of risk perception tend to suggest that personal experience would be expected to affect perceived risk and that the personal relevance of the issue would have a greater effect than a reliance of cognitive information (Howe et al., 2014). As was shown in a meta-analysis by Alló and Loureiro (2014), a direct experience of extreme weather events increases the willingness to accept the costs of mitigation and adaptation policies. Other empirical research has shown that although personal experience with extreme weather conditions and their impacts is connected to a stronger belief in climate change, this association is not considered to be particularly significant (Hornsey et al., 2016). Sometimes, even individuals who have had direct experience with extreme weather events are not necessarily convinced of the need to adopt policies directed at climate change mitigation and adaptation (Gärtner & Schoen, 2021). Interestingly, this relationship also functions inversely, as our perception of our experiences can be influenced by our beliefs, with individuals' opinions about global warming influencing their likelihood of recollecting extreme weather events (Kácha et al., 2022). A feedback mechanism between climate change perceptions and negative effects has also been identified, which suggests that people process cognitive information and affect heuristics simultaneously (Linden, 2014). A perceived susceptibility to climate change was found to be connected to a greater willingness to engage in mitigation activities (Semenza et al., 2011). The phenomenon of self-reported heat stress in urban residents and its associations with coping strategies was the subject of a study by Kunz-Plapp et al. (2016) but the results were inconclusive. This is why more research focused on the relationship between vulnerability and action in urban environment is needed.

1.2 The awareness-action gap

Earlier research into translating perceptions to actions has shown that belief in climate change alone is not a sufficient predictor of the adoption of environmentally friendly activities; indeed, studies suggest that belief is more connected with an intention to act than with actual activity (Hornsey et al., 2016). Perhaps the most methodologically comprehensive and statistically robust work carried out on the topic to date is the paper by Saari et al. (2021), which illustrates that environmental risk perception and

environmental knowledge, mediated by environmental concerns, can be translated into behavioral intention and realization.

In general, one of the more perplexing findings of research into this issue is the complexity of the translation mechanisms from awareness and action, with some studies even refuting the idea that there is a direct link between awareness and action. A number of studies have already shown that awareness of climate change and its impacts offers no accurate prediction of the likelihood of adopting climate-friendly activities, an effect which has been termed the "awareness-action gap" (Csutora, 2012) or the attitude-behavior gap (Farjam et al., 2019). This disparity between different components of environmental awareness is a consequence of the complex nature of reality and economic-structural factors (Csutora, 2012), such as the embeddedness of individual behavior within social and institutional contexts (Jackson, 2005) or the unwillingness of consumers to relinquish unsustainable lifestyles perpetuated by social norms (Sanne, 2002).

1.3 Economic aspects of climate-friendly activities

Previous studies have suggested that varying costs of climate-relevant behavior can have an impact on the adoption of such measures. Some theoretical background is offered in the low-cost hypothesis, which postulates that behavioral costs can influence the effects of attitudes on behavior (Diekmann & Preisendörfer, 2003). In addition to the financial aspects, costs can be viewed in terms of time, discomfort or effort expenditure. According to Diekmann and Preisendörfer (2003), environmental concerns tend to influence ecological behavior to a greater extent when associated with lower costs and inconvenience. Attitudes are more likely to translate into corresponding behavior when the actions are uncomplicated and affordable, but environmental concern alone is insufficient to overcome barriers associated with behaviors that entail high costs or considerable levels of inconvenience (ibid). In such cases, education and financial resources might mediate the connection between belief and action (Stern, 1992). Engagement in low-cost climate-friendly behaviors has been shown to be positively related to factors such as age, levels of concern and the perception of climate benefits (Tobler et al., 2012). In the case of high-cost activities, government bodies could play a role in introducing incentives and cost-reducing measures to motivate climate-friendly actions (Jakučionytė-Skodienė & Liobikienė, 2022).

A correlation has been identified between climate action and environmental injustice (Castán Broto & Westman, 2020). Individuals with lower financial resources encounter barriers in participating in climate-friendly actions as they typically lack the means to invest in expensive measures but also lack access to more affordable activities. In light of this, research into local climate adaptation action has shifted towards poverty-alleviation agendas which are focused on addressing socio-economic disparities and the issue of marginalization. The aim is to examine ways of fostering deeper inclusion and equity within urban climate governance.

1.4 Case study background: Košice

Based on a recent study conducted by the OECD (2023) and the Institute of Environmental Policy of the Slovak Ministry of Environment containing an assessment based on 10 levels of risk, Košice in particular, has been identified as a high-risk district, primarily due to its higher risk of drought (level 8) and extreme heat waves (level 6). In contrast, the risk of extreme precipitation in Košice is relatively low, rated at level 3. Extreme heat was also identified as the most salient climate-change related issue in Košice in studies from the European Environmental Agency (European Environment Agency, 2020), which compiled a list of the observed and projected impacts for seven types of biogeographical regions in the EU. When it comes to conditions for climate action, there is an industrial heritage connected to the still active steel industry and several disused industrial brownfield sites, an environmental burden which poses a challenge (or an opportunity) for future adaptation policies.

In 2022, Košice introduced its first adaptation plan for climate change for 2022–2030, which builds upon vulnerability assessments and recommends specific goals in the climate change adaptation process. The effort to pursue a more sustainable future is also manifested in the city's application for the European Green Capital Award and its participation in the 100 Climate Neutral Cities 2030 initiative. Since 2019, Košice has also been part of the Covenant of Mayors for Climate and Energy initiative, pledging to reduce GHG emissions and

to increase climate change resilience through adaptation strategies. One distinctive aspect of the city lies in the limited engagement of local residents in political participation, a trend which is particularly evident in data concerning local elections. In 2022, Košice recorded the lowest voter turnout for local self-government and mayoral elections when compared to eight cities of similar size and nature. Only 31% of residents participated in the local elections, whereas the average participation rate across the other eight cities stood at 41.2%, with a median of 39.3% (Statistical Office of the Slovak Republic, 2022).

2. Research methodology

The data analyzed in this paper originates from a survey which was primarily conducted in an online format among the residents of Košice from October 2019 to January 2020. The questionnaire was accessible through social media, the web page of the KOŠICE ± 40 project and the web pages of the partners of the project, and information about the questionnaire was also sent by the municipal authorities to all affiliated municipal institutions with the request that it be distributed among their employees. The questionnaire was also distributed to 100 businesses in Košice and was made available in physical format for use in schools and retirement homes. For the purposes of this analysis, only the responses received from Košice residents were considered, with the total dataset consisting of 545 valid responses.

The questionnaire contained questions concerning sociodemographic characteristics such as age, income, education, sex, household size and overall levels of satisfaction. The main focus was placed on attitudes towards climate change, respondents' personal experience with its impact, satisfaction with the availability of information on the topic and measures concerning climate change impacts. The study also aimed to identify the types of climate-friendly activities in which local residents engaged and to gauge their participation in local politics.

Tab. 1 lists a statistical breakdown of the questionnaire respondents. From a demographic perspective, the age of respondents ranged from 15 to 87, with both a mean and median age of 40. Most of the respondents stated that they belonged to the middle-income group. There were slightly more women than men, and most of the respondents had children. Participants stated that they were generally satisfied with their lives. As the survey was voluntary, most of the respondents had a pre-existing interest in the topic of climate change, and this

Tab. 1: Descriptive statistics

Variable	Min	Max	Mean	SD	Median
Age	15.0	87.0	40.2	14.8	40.0
Income	1.0	3.0	2.0	0.5	2.0
Education (years of schooling)	10.0	18.0	16.3	2.4	18.0
Sex (0 = male)	0.0	1.0	0.6	0.5	1.0
Children (0 = no children)	0.0	1.0	0.6	0.5	1.0
Life satisfaction	1.0	5.0	3.9	0.7	4.0
Interest in climate change	0.0	1.0	0.9	0.2	1.0
Subjective vulnerability	0.0	1.0	0.5	0.2	0.5
Citizen engagement	0.0	1.0	0.4	0.2	0.4
Information	0.2	1.0	0.5	0.2	0.5
Engagement in climate-friendly activities	0.0	1.0	0.6	0.2	0.7
Satisfaction with measures	0.0	1.0	0.4	0.2	0.4
Awareness	0.1	1.0	0.8	0.2	0.8

Source: own

resulted in a potentially biased sample with an overrepresentation of people with a stronger interest in the topic.

The focus of our analysis was placed on gaining an understanding of the factors that impact awareness and engagement in climate-friendly activities. This was achieved by formulating nine climate-related variables which were subsequently examined in our models; these variables are listed in Tab. 2.

The variables were examined using the sociodemographic indicators as control variables. The variables were mostly created in the form of indices compiled from the Likert scale responses to the statements provided on the topic.

Tab. 2: Climate-related variables

Variable	Type	Description	Questionnaire item (example in the case of multiple sub-questions)
Awareness	Average score from 2 questions – knowledge and seriousness (see below), adjusted by min-max normalization	(See below)	(See below)
Knowledge*	Index based on the summed scores from 10 statements with Likert scale responses (5 levels), adjusted by min-max normalization	Statements concerning anthropogenic causes of climate change, scientific consensus on climate change, and impacts of climate change	Research shows that climate change is caused by human activity
Seriousness*	Likert scale score (10 levels), divided by 10	Degree of seriousness of climate change as an issue	How serious a problem do you believe climate change to be at the moment?
Vulnerability	Index based on the summed scores from 8 statements with Likert scale responses (5 levels), adjusted by min-max normalization	Statements concerning negative climate change impacts on health, agriculture, infrastructure and property, services or business	Summer heatwaves reduce my work performance (focus/attention)
Engagement	Index based on the summed scores from 8 examples with Likert scale responses (3 levels), adjusted by min-max normalization	Examples of activities indicating engagement in local politics	I participate in local elections
Information	Average score from 2 questions with Likert scale responses (5 levels), adjusted by min-max normalization	Degree of satisfaction with available information concerning climate change impacts and adaptation options	1) Do you feel sufficiently informed about climate change and its impact on Košice? 2) Do you feel sufficiently informed about how to adapt to climate change in the city?
Interest in climate change	Dummy	Interest in climate change	Are you interested in the topic of climate change?
Satisfaction with measures	Index based on the summed scores from 15 examples with Likert scale responses (5 levels), adjusted by min-max normalization	Satisfaction with adaptation measures which are done by the local authorities, primarily in public spaces	E.g., air-conditioning in public buildings (including hospitals)
Climate-friendly activities	Index based on the summed scores from 17 examples (Tab. 4) with Likert scale responses (5 levels), adjusted by min-max normalization	Examples of activities related to adaptation and mitigation	See Tab. 4.

Note: *variable not used directly in the model.

Source: own

Tab. 3 shows the categorization of climate-friendly activities based on their associated costs. It lists all provided climate-friendly activities divided into two categories, based on which dependent variables were created. These groups were assigned intuitively – low-cost activities are mostly behavioral adjustments, such as following extreme weather alerts or sorting the waste for recycling. High-cost activities include examples that are associated with certain material and/or financial resources, such as having air conditioners.

Tab. 3: Climate-friendly activities

	Activity
Low-cost activities	I support the maintenance of green spaces instead of new buildings and parking spaces
	I spend most of my time outside the city (e.g., at a cottage, in the countryside) during hot days
	I compost my bio-degradable waste
	Instead of a private car, I use alternative means of transport which are more sustainable for the environment (walking, bicycle, public transport or car-sharing)
	I drink enough water, keep myself cool and avoid direct sunlight during heatwaves at noon
	Whenever possible, I buy local products and seasonal produce
	I try to minimize my waste production, e.g., by limiting the use of plastic bags
	I sort waste for recycling
	I engage in volunteering activities dedicated to the protection of the environment
	I follow extreme weather alerts
High-cost activities	I use air-conditioning during hot days
	Low fuel consumption was an important feature that I considered when buying a new car
	I changed my holiday plans due to heatwaves (different dates or locations)
	I installed additional shading equipment at home
	I insulated my house/apartment in order to reduce temperate fluctuations
	Whenever possible, I prefer to maintain green spaces on my property

Source: own

In order to analyze the data, we first ran a standard linear model examining the associations between the dependent and explanatory variables while monitoring the effect of the socio-economic factors. We created four OLS models with different dependent variables. The models were checked for multicollinearity and the results were negative. If any heteroskedasticity was detected, robust standard errors were reported. The four regression models were specified as follows (Equations (1–4)):

Model 1:

$$Awareness_i = \beta_0 + \beta_1 * sociodem_i + \\ + \beta_2 * Interest_i + \beta_3 * Vulnerability_i + \\ + \beta_4 * Engagement_i + \beta_5 * Information_i + \\ + \beta_6 * Activities_i + \beta_7 * Measures_i + \varepsilon_i \quad (1)$$

Model 2:

$$Activities_i = \beta_0 + \beta_1 * sociodem_i + \\ + \beta_2 * Interest_i + \beta_3 * Vulnerability_i + \\ + \beta_4 * Engagement_i + \beta_5 * Information_i + \\ + \beta_6 * Measures_i + \beta_7 * Awareness_i + \varepsilon_i \quad (2)$$

Model 3:

$$Activities(cheap)_i = \beta_0 + \beta_1 * sociodem_i + \\ + \beta_2 * Interest_i + \beta_3 * Vulnerability_i + \\ + \beta_4 * Engagement_i + \beta_5 * Information_i + \\ + \beta_6 * Measures_i + \beta_7 * Awareness_i + \varepsilon_i \quad (3)$$

Model 4:

$$Activities(expensive)_i = \beta_0 + \beta_1 * sociodem_i + \\ + \beta_2 * Interest_i + \beta_3 * Vulnerability_i + \\ + \beta_4 * Engagement_i + \beta_5 * Information_i + \\ + \beta_6 * Measures_i + \beta_7 * Awareness_i + \varepsilon_i \quad (4)$$

where: *sociodem* – the set of sociodemographic variables described in Tab. 1; *Awareness, Interest, Vulnerability, Engagement, Information, Activities, Measures* – the variables described in the Tab. 2 and Tab. 3; β_0 – the regression intercept; β_{1-7} – coefficients corresponding to the explanatory variables; ε – error.

The second methodological approach applied an exploratory technique using a machine learning algorithm which was used to validate the regression results and indicate non-linear relations between the investigated concepts. The random forest (RF) technique developed by Breiman (2001) was applied in this process. Our study adopted a bagging algorithm using the "randomForest" R Package based on Breiman and Cutler's random forests for classification and regression. The parameters were set as follows: first, the number of trees to grow was set to 500, and the number of variables randomly sampled as candidates at each split was set to 5. After running the model, the out-of-bag mean squared error stabilized at around 150 trees and there was no additional gain in increasing the number of trees. This method was applied in order to identify any potential hidden relationships that could not be described by the standard linear model. This was intended as an exploratory step to either confirm the results of the previous models or to suggest further improvements in potential future research. As there was no intention to make inference statements, it was not considered necessary to divide the data into the training and testing sets. Similar machine learning algorithms have been used in other studies, e.g., by Lee et al. (2015), which examined the predictors of climate change awareness and risk perceptions in different countries. The study selected this method due to its high predictive accuracy and capacity to provide an unbiased and robust ranking of predictor importance and account for complex interactions between predictors and unbalanced response classes while preserving as much information in the data as possible. The analysis also avoided the need to divide the sample into training and testing sets, as the prediction accuracy for each model was calculated using a built-in out-of-bag test sample provided in the R function of the package (this option was also selected in our analysis).

3. Results and discussion

3.1 Results

The results from the first model examining factors associated with climate change awareness revealed several key findings. The most significant explanatory variable was subjective vulnerability, indicating that individuals who perceived themselves as vulnerable to the impacts of climate change were more likely to be aware of the issue. Additionally, interest in the topic of climate change emerged as an important factor, suggesting that individuals with a general interest in climate change were more likely to be aware of its implications. The results also indicated a negative relationship between age and awareness, indicating that younger people tended to be more concerned about climate change. Overall, the model accounted for 27% of the variance in the dependent variable. The findings indicate that individuals who are aware of climate change are typically younger, have an existing interest in the topic, and have personally experienced the effects of climate change in their everyday lives.

Several significant predictors were identified in the second model, which explored the factors associated with engagement in climate-friendly activities encompassing both mitigation and adaptation measures. Citizen engagement emerged as the most effective predictor, suggesting that individuals who actively participated in climate-friendly actions were more likely to engage in such activities. Subjective vulnerability also played a significant role, indicating that those who perceived themselves as vulnerable to climate change were more likely to engage in climate-friendly actions. Age and satisfaction with the information provided on climate change and adaptation strategies were positively associated with the dependent variables, suggesting that older individuals and those who felt adequately informed were more likely to engage in climate-friendly activities. Gender was also a relevant factor in this model, with male respondents displaying a more negative association, although the significance level was relatively low. Overall, the model accounted for 30% of the variance in the dependent variable. The results from this model suggest that individuals who engage in climate-friendly

Tab. 4: OLS results

	Estimate, std. error and significance			
Variables	**Awareness**	**Activities**	**Activities (cheap)**	**Activities (expensive)**
Intercept	0.484 (0.066)***	0.103 (0.076)	0.278 (0.077)***	−0.131 (0.098)
Age	−0.002 (0.001)**	0.002 (0.001)**	0.001 (0.001).	0.002 (0.001)**
Income	0.026 (0.016).	0.017 (0.013)	−0.012 (0.013)	0.059 (0.019)**
Education	0.003 (0.002)	0.000 (0.003)	0.000 (0.003)	0.000 (0.004)
Sex (male)	−0.022 (0.013)	−0.033 (0.014)*	−0.048 (0.013)***	0.000 (0.018)
Children	−0.012 (0.016)	0.008 (0.017)	−0.027 (0.016).	0.063 (0.023)**
Life satisfaction	−0.006 (0.009)	0.014 (0.010)	0.011 (0.009)	0.014 (0.012)
Interest in climate change	0.209 (0.030)***	0.046 (0.037)	0.050 (0.038)	0.027 (0.040)
Subjective vulnerability	0.217 (0.039)***	0.178 (0.038)***	0.086 (0.036)*	0.286 (0.047)***
Engagement	−0.007 (0.040)	0.264 (0.034)***	0.289 (0.033)***	0.156 (0.041)***
Information	−0.001 (0.007)	0.017 (0.007)*	0.023 (0.007)**	0.018 (0.049)
Activities	0.084 (0.058)			
Satisfaction with measures	−0.068 (0.044)	0.084 (0.050).	0.064 (0.051)	0.095 (0.058).
Awareness		0.093 (0.064)	0.117 (0.063).	0.031 (0.063)
N	545	545	545	545
Adjusted *R*-squared	0.275	0.307	0.296	0.199

Note: Significance codes: *** 0; ** 0.001; * 0.01; . 0.05.

Source: own

activities are more likely to be women who are active citizens with personal experience of the negative effects of climate change and feel that they have sufficient information on adaptation measures. Additionally, the level of engagement tended to increase slightly with age.

The third model focused on climate-friendly activities that are inexpensive or cost-free. Similar to the previous models, citizen engagement emerged as a significant factor, indicating that individuals who actively participate in these low-cost activities were more likely to engage in climate-friendly behaviors. Vulnerability and satisfaction with information also played relevant roles, suggesting that individuals who perceived themselves as vulnerable to climate change impacts and felt adequately informed were more likely to engage in such activities. Gender showed a high significance in this context, although the magnitude of the effect was not substantial. The model accounted for approximately 30% of the variance in the data. This model suggests that individuals engaging in inexpensive climate-friendly activities are likely to be women who are also involved in local politics and do not perceive a lack of available information on adaptation measures.

The predictive power of vulnerability and citizen engagement remained high in the fourth model, which examined expensive climate-friendly activities, but a new variable emerged as relevant: the parental status of respondents. Individuals with children were found to have a higher likelihood of engaging in expensive climate-friendly activities. Additionally, higher incomes and advanced age were associated with an increased likelihood of participating in these activities.

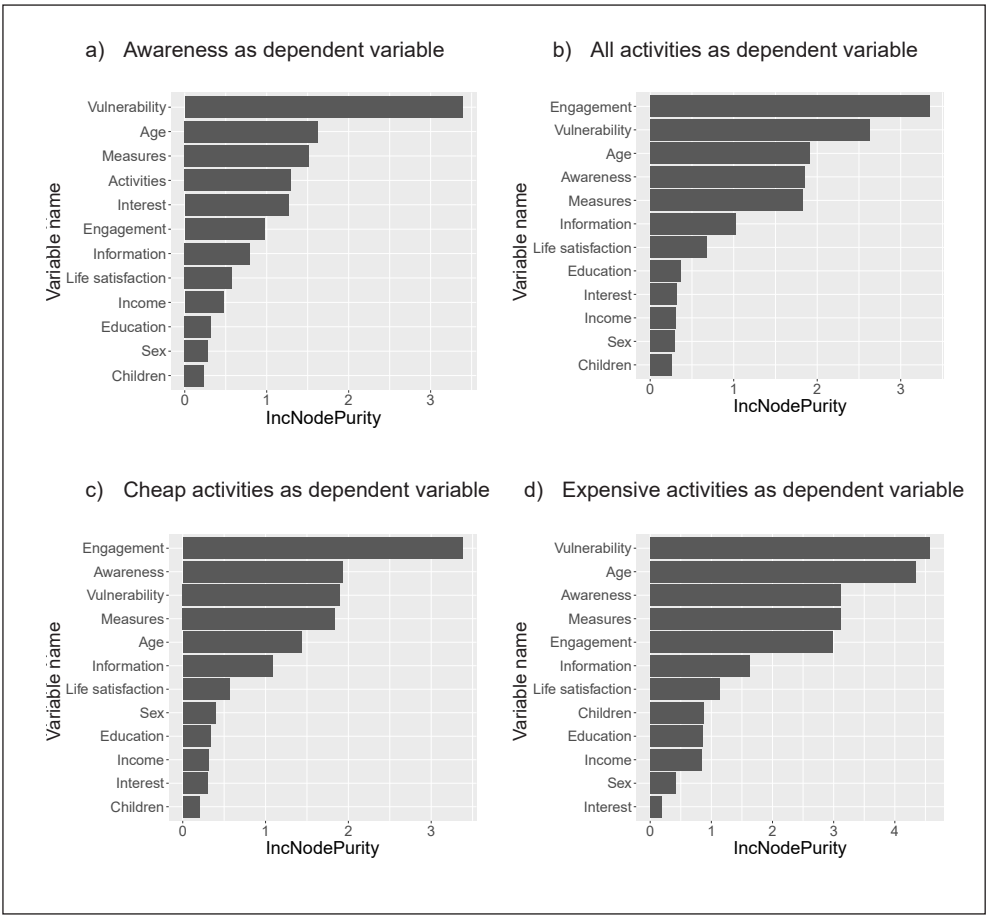

Fig. 1: Importance of variables in random forests models

Source: own

Overall, the models did not identify a high proportion of variance in the dependent variable, as the adjusted *R*-squared rate was between 0.2–0.3. However, it should be noted that this is a common occurrence in social science research, and similar studies achieve comparable values in this metric (e.g., Rosentrater et al., 2013; Shi et al., 2015).

The final part of the analysis examined possible non-linear relationships between the dependent and explanatory variables. The direction of the relationships was not the main focus of this analysis as this characteristic cannot be identified using the random forests algorithm. The random forests model can be interpreted using feature importance values which are relative in the model and are therefore not numerically significant. These values are used to rank the input variables that influence the target variable. The random forests algorithm allows us to identify the variables most responsible for decreasing variance through node purity, thereby determining the most important features for predicting the dependent variable. The derived feature importance is shown in Fig. 1a–1d as IncNodePurity, a value representing the total decrease in node impurities measured by the Gini index. The expressed measure relates to the decline in purity when a specific variable lacks information. In scenarios where a variable

possesses no initial information, the resultant decline would amount to zero.

The first random forests model examines the predictors associated with "awareness" (Fig. 1a). The most important independent variable is that of self-assessed vulnerability, followed by age and satisfaction with measures. Among the least important variables are sociodemographic characteristics "children," "sex," "education" and "income."

The results of the second model (Fig. 1b) confirmed that citizen engagement in local politics ("engagement"), vulnerability and age might help explain the variance of climate-friendly actions. Satisfaction with local adaptation measures (the "measures" variable) was also found to be a good predictor of climate-friendly action. In contrast to the findings of the regression results, awareness was only the fourth most important variable, although it is at a comparable level of importance with age and satisfaction. This suggests that awareness might still matter but that the relationship cannot be described by a linear model. With the exception of age, the sociodemographic variables were assessed as having low predictive power.

The two models investigating the predictors of engagement in the case of low and high cost climate-friendly activities differ slightly in their results (Fig. 1c–1d). Corroborating the results from the OLS, engagement in politics was found to play a crucial role in explaining engagement in cheaper climate-friendly activities. Subjective vulnerability, awareness and satisfaction with measures showed broadly similar levels of importance. Employing expensive measures was associated with vulnerability and age, followed by satisfaction with measures, awareness and engagement in local politics. The low-cost hypothesis could not be reliably confirmed by the above models, as awareness ranked among the most important variables for both low and high cost activities. As with the regression results, age plays a more important role in explaining engagement in high-cost activities rather than cheaper measures. This could be due to the straightforward correlation of age and wealth rather than income, a value which was controlled for in the analysis.

3.2 Discussion

Our analysis not only confirms the previous findings on the factors affecting climate change awareness and action in general, but also sheds light on the topic in the under-researched context of the urban environment and relates it to engagement in local politics. The significance of sociodemographic attributes, notably age, sex, income and parental status outlined, e.g., in Gifford and Nilsson (2014) or in Hornsey et al. (2016), was validated across various model specifications. The role of age was evaluated as highly important in the non-linear models but as somewhat less salient in the linear analyses. This interpretation is in agreement with earlier research into the prediction of climate change awareness, which also indicated that awareness was more profound in the case of younger people (Hornsey et al., 2016). The nature of the results relating to the prediction of action is even clearer when activities are divided in terms of cost, with age becoming positively associated with a higher probability of engaging in more expensive activities. This interpretation is intuitive when we examine the specific activities that were included in the survey, such as making home improvements, choosing vacation destinations, or buying a new car, activities that are naturally more typically associated with later adulthood than with young age. Furthermore, the positive coefficients associated with income and having children which were noted in the case of expensive activities, are also intuitive. These characteristics were only found to be relevant in this one model, which suggests that parents with higher incomes have the means and/or the motivation to engage in more costly adaptation-related activities. In the previous literature, income was found to be positively correlated with climate change beliefs (Hornsey et al., 2016).

One aspect of the findings which differed from those of earlier studies was the level of education; this factor was not found to be relevant in any of the models in our study. This missing link perhaps deserves further research that considers the specific conditions of different education systems. The findings suggest that in Slovakia, a post-socialist country which still enjoys a significant degree of egalitarianism in its education system, the influence of education may be less significant than in other countries. Or, as suggested by Czarnek et al. (2021), the effect of education could be dependent on the political ideology and/or the level of the country's development. This could mean that Slovakia is among the developed countries, where the positive effect of education is attenuated by the right-wing ideology.

On the other hand, our research did confirm the connection between sex and engagement in climate action. We found that women were more likely to take part in low-cost mitigation and adaptation activities, a finding which could be explained by earlier research which has associated the different stances towards adaptation to climate change among male and female respondents to the factor of motivation – men are more likely to be motivated by financial reasons and advances in technology, while women tend to be more egalitarian and prioritize the community and ecological aspects of measures (Alló & Loureiro, 2014; Brink & Wamsler, 2019).

In the case of psychological factors, we found that personal experience with negative impacts of climate change in everyday life is of great importance in both awareness and all types of activities. In the literature, this relationship has been found to vary, with some studies postulating that experience increases support for climate policies (Alló & Loureiro, 2014), while others finding that some people do not find their experience convincing of the need to adopt policies directed at climate change mitigation and adaptation (Gärtner & Schoen, 2021). In addition, a cognitive aspect to the awareness-action gap was identified. This is in line with the hypothesis that personal experience is also responsible for shaping human behavior rather than cognitive information alone. This means that in order to become fully aware and willing to take action, urban residents need to internalize not only their knowledge of the issue, but also the connection between their negative experiences and the reality of climate change. In addition, the availability of information about how to adapt to climate change has been found to motivate low-cost behavior. This finding is in line with those reported by Shi et al. (2015) which identified a nexus between action-related knowledge (in our case, information about possible ways of adapting) and a willingness to adjust behaviors.

In practice, the findings of the study are of great importance for policymakers' communication strategies. The information that stresses the direct relationship between climate change and peoples' exposure to the consequences of heatwaves, flash floods, or drought will be the most efficient means of conveying the desired message and motivating action among local populations. Indeed, by providing guidance on how to mitigate the impacts of climate-related changes, local authorities could also foster further activities. However, in order to gain support for climate change policies, the authorities should communicate through causal knowledge and avoid interfering with peoples' cultural values (Shi et al., 2015). In addition, result-oriented communication focusing on the uncontrollable consequences of climate change should be avoided, as this could engender feelings of resignation and helplessness (ibid).

Another important aspect to consider when designing policies and communication strategy is the economic cost of climate-related adaptation and mitigation activities. This aspect of the issue increases in importance when we take into account the urgency of costly adaptation measures. Although we found that the availability of information on adaptation measures might help to motivate engagement in low-cost activities, it is imperative to consider the potential downsides of such an approach, with engagement in low-cost behaviors potentially undermining more expansive efforts to mitigate climate change through costly yet effective action (Hagmann et al., 2019). Environmentally concerned individuals reduce the cognitive dissonance between their attitudes and the impacts of their actions through low-cost behaviors, which subsequently lessens their need to engage in costly behaviors. Attempts to offer quick fixes to complex problems such as climate change always have the potential to backfire and result in unforeseen consequences (ibid).

Additionally, the connection to climate justice is an important aspect to consider in the interpretation of the results. Climate justice emphasizes the equitable distribution of the burdens and benefits of climate change and the fair participation of all individuals and communities in decision-making processes. In the context of local climate governance, it is crucial to assess whether certain demographic groups, particularly those who may be more vulnerable to the impact of climate change, have equitable access to information, resources, and opportunities for engagement in climate-friendly activities. Our case study indicated lower levels of involvement among older sections of the population.

Earlier studies have emphasized the importance of identity (Hornsey et al., 2016), and this can also be implied from our results concerning the impact of engagement in local

politics. Active participation in local political and civic life greatly increases the likelihood of engagement in climate-friendly activities. We can also suggest the possible existence of an "activist" identity that, although it could not be measured directly in the survey, can still be discerned in the observed data. When designing measures, local policymakers can capitalize on the motivation of these already active citizens, who can serve as inspirational role models for their communities. Further research on climate perceptions and climate-friendly behavior in cities could further explore how to build upon the connection between attachment to place and action. Promotional activities related to building a city's brand and identity could potentially enhance local citizens' engagement in climate-friendly activities. Additionally, this could suggest that supporting civil society represents an indirect contribution to the fostering of adaptive activities. Allocating resources to community-building initiatives and promoting participatory climate governance is particularly effective in cities with lower levels of citizen engagement, such as Košice.

There are limitations connected to the sample and the sampling method employed in the survey. Although our data is derived from a relatively large sample of questionnaire responses, the sample was potentially biased as many of the respondents to the questionnaire showed a pre-existing interest in the topic of climate change. People with higher educational attainments were also overrepresented in the sample, and there were relatively few respondents from low-income brackets. As a result, future research should ensure that respondents are selected irrespective of their interest in the topic and should also make an effort to include marginalized groups. Previous research has also shown that awareness and action can be heavily influenced by pre-existing values and identities, and therefore, surveys which aim to map climate change perceptions should also attempt to collect responses on these topics in order to ensure a more balanced dataset.

Conclusions

The identification of the co-founding factors of climate change awareness and subsequent action represents a crucial step in understanding the mechanisms which should be employed in order to ensure the successful adoption of adaptation and mitigation policies across different demographic groups. Our study not only confirms the general principles identified in earlier research but also offers a specific context related to urban residents and local politics. The main contribution to the existing literature is twofold – first, by accounting for the local context, we addressed the debate on climate change adaptation at the most important level – cities. Second, by choosing Košice, we provided a case study of the under-researched geographical area, which has its specific conditions.

As for the comparison with the existing research, the analysis has confirmed multiple sociodemographic characteristics outlined in e.g., Hornsey et al. (2016) as having an impact on either awareness or engagement in climate-friendly activities. Those with higher awareness levels tend to be younger and those more engaged are usually women. The missing link between education and climate beliefs can be explained by politization of the topic in developed countries (Czarnek et al., 2021). Our findings on the role of subjective vulnerability contributes to conflicting results of the previous researchers, e.g., Kunz-Plapp et al. (2016) or Gärtner and Schoen (2021), indicating that own experience with negative impacts might indeed motivate people to act. When it comes to the previous research on the economics aspects, attitudes were found to be more likely to translate into corresponding behavior when the actions were uncomplicated and affordable, but environmental concern alone was found to be insufficient to overcome barriers associated with behaviors that entail high costs or considerable levels of inconvenience (Diekmann & Preisendörfer, 2003). Our analysis could not completely confirm this (due to borderline low significance level), but we found that having information matters when it comes to low-cost measures.

The results of the study draw attention to several policy implications. As the findings suggest that cognitive awareness alone might not be sufficient to motivate people to act, awareness-raising campaigns should not necessarily be seen as the most effective means of achieving higher levels of engagement and it might be more effective to confront people with the impacts of climate change through their own experience and vulnerability. As a result, approaches which place a greater

emphasis on the direct connection between climate change and its immediate manifestations in the local environment and on peoples' everyday lives could potentially motivate local residents to become more actively involved in mitigation and adaptation activities. As previous studies have suggested, the availability of action-related information was found to affect individuals' willingness to act. This means that communication strategies should also include recommendations for specific climate-friendly activities and their potential effect.

We also identified a connection between climate-friendly action and participation in local politics, but we do not view this nexus as a causal relationship but rather as co-occurring phenomena, a correlation which could be a manifestation of an as-yet undetermined activist identity. From this perspective, participatory community-building activities organized by local stakeholders ranging from local authorities to NGOs or other actors could encourage those who hesitate to engage on their own, an approach which might be more effective than campaigns focused on raising awareness. The sense of identity engendered by belonging to a group with an activist identity can also promote citizen engagement in a broader sense.

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