Humanities & Social Sciences Communications

ARTICLE

https://doi.org/10.1057/s41599-023-01953-y OPEN

Assessing climate justice awareness among climate neutral-to-be cities

Nives Della Valle [1]✉, Giulia Ulpiani[1] & Nadja Vetters[2]

This paper sheds light on the importance of evaluating climate justice concerns when forging climate-neutral strategies at the city level. Climate justice can be a useful policy lever to develop measures that promote simultaneously greenhouse gas emissions reductions and their social justice dimension, thus reducing the risk of adverse impacts. As a result, evaluating policymakers' awareness of (i) recognition (ii) distributive (iii) procedural, and (iv) intergenerational issues about the transition to climate neutrality might help identify where to intervene to ensure that decisions towards more sustainable urban futures are born justly and equitably. This study uses data from the European Mission on 100 Climate Neutral and Smart Cities by 2030 and a principal component analysis to build an index of climate justice awareness. It then identifies control factors behind different levels of climate justice awareness. The empirical analysis suggests that the more cities are engaged in climate efforts, the more they implement these efforts considering also the social justice dimension. It also reveals that the geographical location and the relationship with higher levels of governance contribute to shape the heterogeneity in a just-considerate climate action by virtue of different governance structures, historical legacies, and economic, cultural, and political characteristics. Overall, the analysis unveils that the availability of governmental support in capacity building and financial advisory services, and the breadth of the city's legal powers across different fields of action are positively related to justice awareness. Conversely, the perception of favourable geo-climatic conditions is negatively correlated. These relationships can be read as assistance needs that cities perceive in their pathway to just climate neutrality and highlight where future efforts in research and policy-making should focus in the following years to pave the way to a just transition.

[1] European Commission, Joint Research Centre, Ispra, Italy. [2] European Commission, Joint Research Centre, Brussels, Belgium.
✉email: nives.della-valle@ec.europa.eu

Introduction

Since before the United Nations Framework Convention on Climate Change (UNFCCC) was established in 1992, climate change discussions have included justice concerns. However, it is only in recent years that the concept of climate justice has become prominent in climate academic and policy debates. We can now clearly understand climate justice as justice in relation to (i) the responsibility for climate change and its impacts, or (ii) the effects of responses to climate change (Newell et al., 2021). We can also link it to the 'triple injustices' of climate change (i.e., uneven distribution of impacts, uneven responsibility for climate change, and uneven costs associated with mitigation and adaptation (Roberts & Parks, 2015), wherein those who are the least responsible for greenhouse gas emissions are also those who are most vulnerable to their impacts and most disadvantaged by responses to climate change (Krause, 2021). In this study, we understand climate justice in relation to the effects of responses to climate change.

Despite the academic interest in climate justice has increasingly gained momentum, several scholars have debated on its operational value, as it might remain only normative and theoretical (Hughes & Hoffmann, 2020; Schlosberg & Collins, 2014). As an example, Brisley et al. (2012) emphasise that there are no specific metrics available to assess the inclusion of justice dimensions in climate policies. In this study, we aim to uncover the operational value of climate justice by evaluating justice concerns in climate decision-making processes. In particular, we build on the proposal advanced by Sovacool et al. (2017) that justice frameworks can serve as decision-making tools that can assist planners in making policy choices capable to address both the climate change and the social justice goals. In this case, planners and regulators are "justice aware". However, assessing justice concerns is a challenging task, as there might be heterogeneity in how these are conceived and addressed, depending on the context and the governance level (Chu & Cannon, 2021). Indeed, embedded in the very definition of climate justice are the pillars of territorial cohesion and multi-level governance, with national, regional, and local actors all called upon.

In this study, we focus on the local, notably urban, level. Cities are locations where developing measures against climate change is highly urgent (Nevens & Roorda, 2014) and where opportunities for co-creation with the civil society are abundant. In particular, urban areas in the developed world account for more than 70% of energy-related global greenhouse gases from the supply side (Bellucci et al., 2012), and the share would be even higher in terms of consumption (Hoornweg et al., 2011). Additionally, the majority of the global population lives in cities (United Nations, 2019). At the same time, there is an increasing consensus on the key role that cities can play as agents of change in addressing global climate change (van der Heijden et al., 2019). During the late 2000s, cities began to emerge as alternative hubs for political leadership, technological advancement, and financial support in advancing climate action (Bulkeley, 2010). They are exposed to activities, processes, or patterns, which make them the perfect loci to implement mitigation and adaptation efforts (Diana Reckien et al., 2015). In fact, cities can be seen as "natural" sites for innovative and experimental climate action in a progressive direction (Evans et al., 2016). Municipalities themselves recognised their key role in global climate mitigation and adaptation, and committed to take concrete steps to combat the climate crisis, as announced by over 100 cities at the end of the UN's Climate Action Summit in 2019 (Salvia et al., 2021). Further, a number of city-dedicated initiatives to deliver on the European Green Deal have been promoted to catalyse a capillary reaction to climate change at the sub-national level, including the Covenant of Mayors—that gathers 10,000+ signatories committed to climate change mitigation and adaptation—and the European Mission on 100 Climate-Neutral and Smart Cities (hereinafter, the Cities Mission), through which cities will pursue climate neutrality by 2030 and will thereby design and implement ambitious climate mitigation plans while elaborating on the green, digital, and just attributes of the transition.

Although these ambitious cities are ideal contexts where both environmental and social justice goals can be achieved, due to the relatively short distance between municipalities and citizens, compared to other governance levels (Evans, 2011), they can be hot spots of injustices, which manifest in multiple ways, including displacement, destructive redevelopments or uneven investments that may exacerbate inequalities (Phillips et al., 2022). That is why, to express their full potential as agents of change in addressing global climate change (Bouzarovski & Haarstad, 2019), cities need to be able to recognise the link between the planned climate efforts and their multiple implications to avoid generating or exacerbating forms of injustice (Hughes & Hoffmann, 2020). In short, cities need to be justice-aware when developing climate action and the degree of awareness should become an indicator and a lever to guide and course-correct climate policy so that truly resilient and future-proof urban decisions can be taken.

This study aims to uncover the operational value of climate justice by providing a quantitative, ex-ante assessment of climate justice considerations in urban climate action planning. The proposed methodology overcomes the uncertainties in terms of robustness, comparability, and interpretability of results that come with the conceptual approaches and/or limited city samples that characterise the existing literature on the topic. Instead of qualitatively analysing a set of climate plans, we leverage the newly collected Cities Mission dataset as an unprecedented portray of where hundreds of European cities stand in terms of climate mitigation against the background of a common and well-defined framework and climate ambition. The dataset connects scientific and technological aspects to policy-making, risk anticipation and cross-sectoral integration to social equity, as co-ingredients of a robust and just climate neutrality strategy, across multiple dimensions and highly diverse urban contexts. Relying on data that are elicited through a homogenous procedure (i.e., survey), descriptive of a significant sample of respondents, and related to a well-defined climate action programme, enables us to develop a scientifically sturdy European index of climate justice awareness. The index and its analysis are instrumental not just to compare cities and determine a Europe-wide baseline, but also to identify predictors and to delineate the opportunity space for enhanced justice awareness.

Indeed, even among the most ambitious cities in climate mitigation and adaptation, there might be considerable heterogeneity in climate action, due to city-specific factors (Diana Reckien et al., 2015). As an example, when cities are prosperous (high GDP per capita) and populous, or when they have the financial capacity and the know-how to implement climate action, they may engage more in climate action (Intergovernmental Panel on Climate Change, 2015; Diana Reckien et al., 2015). In contrast, when they are constrained in their powers and boundaries, due to, e.g., regulatory limitations, cities may not express their full potential in exerting climate efforts (van der Heijden et al., 2019). At the same time, city-specific factors might limit climate justice considerations. For instance, when cities are limited in an operational capacity, they might concentrate their efforts towards "profitable" climate initiatives for which quantifiable emissions reductions can be demonstrated and investors can be lured, at the expenses of more socially attentive initiatives whose benefits are less conventionally tangible (Castán Broto & Westman, 2020).

In this study, we investigate these potential mechanisms and empirically address how climate engagement, as measured by a combination of metrics of engagement, preparedness, and ambition in climate action, is related to climate justice awareness in policy-making across the procedural, distributive, recognition, and intergenerational pillars, and which city-specific factors (such as climate, population, GDP) may serve as predictors of climate justice considerations. To this aim, through principal component analysis (PCA), we create an index for climate action that reflects cities' efforts in climate mitigation and adaptation strategies and initiatives, as well as their GHG emissions reduction targets. The index is then used as an explanatory variable for a second index aimed at quantifying the level of climate justice awareness that equally accounts for the consideration of the four justice pillars. Finally, by adopting a regression approach, we study the relationship between climate justice awareness and climate engagement, including a set of control variables to account for local specificities and influential factors that could contribute to the different manifestations of just climate action across European cities.

Theoretical framework

Cities are ideal contexts where both environmental and social justice goals can be achieved, due to the relatively short distance between municipalities and citizens, compared to other governance levels (Evans, 2011). Despite this potential, there is evidence that, so far, city climate plans have commonly failed in embedding social justice, resulting in an increased social divide and in disproportionate vulnerabilities to weather extremes, air pollution, and social marginalisation (Reckien et al., 2023; Wachsmuth et al., 2016). There is a general lack of accountability for the various adverse impacts that may be triggered by climate action, notably (i) beyond wealthy districts, (ii) at the periurban or rural fringes, and (iii) at the metropolitan/regional level (e.g., in functional urban areas). This suggests not only that the climate action at the city level needs to be attentive to more global processes to avoid a mere displacement of injustices and unsustainable practices (Angelo & Wachsmuth, 2015, 2020), but also that cities should adopt a more holistic approach than that based only on technical perspectives (Chu & Cannon, 2021).

Against this backdrop, a body of academic work has emerged to criticise technocratic approaches, which often prioritise regulatory, financial, and engineered interventions, while neglecting the social, cultural, and economic inequities (Meerow & Newell, 2019; Shi et al., 2016). These critiques are particularly relevant within urban environments that are already marked by high levels of inequality, characterised by contentious issues like the marginalisation of the vulnerable (Chu & Cannon, 2021). In this regard, scholars have observed that public policies and plans have played a key role in reinforcing systemic injustices, both directly and indirectly (Brand and Miller, 2020). As an example, some cities that initiated measures to promote adaptation started safeguarding economically significant land from anticipated risks, implementing exclusionary zoning and land use policies to preserve property values, and prioritising the enhancement of infrastructure and public services in affluent neighbourhoods (Long & Rice, 2019). Consequently, scholars began to raise concerns about how these plans were contributing to displacement, perpetuating poverty, and, in certain instances, exacerbating vulnerability to climate effects in historically marginalised communities (Anguelovski et al., 2016).

A stream of research has thus emerged, to address these critiques by looking at operationalising justice frameworks to enable climate action policy choices to address both the climate change and the social justice goals (Sovacool et al., 2017). This stream of literature posits that when planners and regulators take into account justice dimensions from the very start of the decision-making process, then also the implementation of strategies and plans is more likely to be able to address both the climate change and the social justice goals (Juhola et al., 2022). Practically, this calls for a need to evaluate the degree of justice awareness in climate action planning.

Despite the conceptual advancement in climate justice, however, there continues to be limited empirical evidence on how justice dimensions are actually integrated into urban climate planning. The few exceptions, like the studies by Chu and Cannon (2021) and Juhola et al. (2022), assess the inclusion of justice dimensions in climate action plans of a limited sample of cities by deriving interpretative justice indicators. However, this methodology and the availability of limited city samples can make it hard to extract comparable results for large regions, like those that characterise Europe, and to derive quantitative relationships to inform decision-making.

This study enriches this stream of research aiming to uncover the operational value of climate justice by evaluating how justice concerns are taken on board in urban climate action planning. To this aim, we refer to the framework of climate justice, which is based on environmental justice (Schlosberg & Collins, 2014). Over time, the framework of environmental justice has undergone a gradual transformation, leading to the recognition that an inequitable distribution of environmental burdens and benefits is not inherently predetermined, but rather has underlying causes. Consequently, four dimensions crucial to achieving justice in the context of mitigating and adapting to climate change have been commonly identified and recognised as interconnected: recognitional, distributive, procedural, and intergenerational (Newell et al., 2021).

Recognitional justice manifests in understanding differences while guaranteeing equal rights for all (Newell et al., 2021). It translates into acknowledging the diverse needs of different societal groups in order to minimise social costs associated with climate action. This is because vulnerabilities to climate risks are situation-dependent (Fitzgibbons & Mitchell, 2019). Understanding the significance of underlying social structures is essential for identifying the factors that contribute to social injustices within societies, as these contribute to determine the way the most vulnerable will experience the impacts of climate change and climate action (Schlosberg, 2004). Therefore, including recognitional justice in climate action means not only to assess whether climate action recognises and addresses varying needs across different segments of society, but also whether it acknowledges the influence of societal structures on disadvantaged communities (Juhola et al., 2022).

Equity is often understood as coterminous with distributive justice. It refers to a state where resources, opportunities, and protection from climate hazards or risks are distributed in an equal and fair manner, regardless of the background or identity of individuals or groups (Chu & Cannon, 2021). Climate action itself might be associated with an unequal distribution costs and benefits, and this inequality might occur both locally and nationally (Colenbrander et al., 2018). As an example, developing a flood defence in one area may increase flood risk in downstream populations (Eriksen et al., 2021). This implies that addressing distributive justice in climate action translates not only in estimating the climate hazards and risks, but also how these are distributed across the different social groups (Fiack et al., 2021). Additionally, it translates in assessing which costs and benefits climate action will generate, and how these will be distributed across the social groups (Juhola et al., 2022).

Procedural justice refers to fair, accountable, and transparent processes that aim to engage all stakeholders in a non-

discriminatory way (Sovacool & Dworkin, 2014). Notably, transparent, accountable, and inclusive decision-making processes and procedures become just when they incorporate a variety of voices, values, and perspectives (Mundaca et al., 2018). This implies that cities address procedural justice in climate action when they strive to make a variety of groups represented in as many different phases of planning process as possible, and take on board different ideas even when this implies substantial changes (Juhola et al., 2022).

Finally, climate change and climate action present a significant challenge to account for considerations of notions of intergenerational justice. If left unchecked, it would result in an unjust burden caused by climate change (or failed climate action) placed upon future generations by those in the present (Gonzalez-Ricoy & Rey, 2019). Intergenerational justice has renewed traction owing to the Fridays for Future movement, yet it dates back—at least—to the report *Our Common Future* (World Commission on Environment and Development, 1987). This report conceived sustainable development as the ability of current generations to meet their needs without compromising that same ability of future generations (Newell et al., 2021). Therefore, urban climate action accounts for intergenerational justice concerns when future interests are explicitly represented and taken on board (Lawrence & Köhler, 2017).

Data and methods

Against this theoretical framework, this study focuses on a group of particularly ambitious cities in climate action; those that expressed interest in the Cities Mission. The Cities Mission aims to promote the transition to climate neutrality in 100+ cities by 2030. The definition of climate neutrality standing within the Cities Mission framework requires reaching (net) zero emissions across i) all highest emitting sectors (e.g., energy, transport, waste, industry, agriculture), ii) all emissions scopes (direct and indirect emissions within the city boundary and out-of-boundary emissions related to the disposal and treatment of waste/wastewater generated within the city boundary), and iii) seven greenhouse gases (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3). In total, 112 cities were selected for this ambitious programme from the 362 that participated in the call for Expression of Interest (EOI) closed on 31 January 2022. The EOI took the form of an all-encompassing questionnaire of 374 questions designed to provide:

(i) a systematic and complete assessment of the city's starting point (preparedness) and demonstrated engagement in climate action (engagement);
(ii) an evaluation of the consistency, plausibility, and credibility of the commitment and capacity to reach climate neutrality by 2030 (ambition);
(iii) and a preliminary assessment of the familiarity with integrated approaches and holistic thinking in climate action through co-benefits analysis, barriers identification, and risk anticipation.

The EOI questionnaire and the data collection were entirely designed and managed by the European Commission. Cities were given a link to access the online questionnaire. The link could be shared by the city administration to anybody in the (best) position to answer the questions to ensure a compelling candidature.

The analysis is based on data from all the 362 cities that answered the EOI questionnaire and thus expressed the ambition to go emission-free in less than a decade (see Fig. 1). The sample includes cities from 35 countries encompassing all EU Member States with varied sizes, from large and medium cities (above 50,000 inhabitants, up to 15 million inhabitants) to smaller ones (down to around 10,000 inhabitants). The starting point in climate action is also significantly diverse across cities, with different baseline emissions, trends, and familiarity with dedicated policies and strategies (Ulpiani et al., 2023).

To enable the evaluation of climate justice awareness (CJA) and climate engagement (CE), we relied on a set of selected EOI questions (see Table 1 and for more details on the questions' description in Table A.1 in the Supplementary Appendix), including both multiple and single choice questions.

The questions that were used to develop the climate justice awareness index were designed and selected based on the four main pillars of climate justice (Newell et al., 2021).

As *procedural* justice concerns the various processes and elements of climate decision-making that might involve the regulation of the distribution of goods (Walker & Day, 2012), it translates in providing access to relevant information, or legal procedures to enable to claim participation rights, recognising and acting upon unjust procedures, and striving to address biases on the side of project proponents and/or decision-makers (Mundaca et al., 2018). Therefore, the selected questions tried to capture whether the various key groups are usually engaged in climate planning and how.

Distributive justice concerns the inequalities in access to social goods and ills, like energy, water, pollution, or food (McCauley et al., 2013; Sovacool & Dworkin, 2015; Walker & Day, 2012). In particular, one of the key aspects of distributive justice is the identification of how goods and ills are distributed across the society (Newell et al., 2021). Hence, the selected questions capture whether cities estimate costs and benefits associated with climate action and climate change, and whether social redistribution is considered to mitigate costs.

Recognitional justice is closely linked to procedural and distributive justice, being concerned with the capacity to acknowledge the existence of different needs (energy, water, health, etc.) across the society (Walker & Day, 2012), notably the needs of the socially and politically marginalised, including the energy poor (Della Valle & Czako, 2022). Therefore, the selected questions tried to capture whether cities acknowledge the existence of different (structurally shaped) needs (energy, water, health, etc.) across the society.

Finally, as *intergenerational justice* concerns protecting future generations from harm, providing them with the same resources current generations are enjoying, and with means to express their voice in climate change discussions (Sanson & Burke, 2020), the selected questions tried to capture whether future generations' interests are considered or represented by younger generations.

Following the selection of the questions developed to reflect each of the four pillars, as many indexes were created: (i) *recognition (RJ) (ii) distributive (DJ) (iii) procedural (PJ), and (iv) intergenerational* justice (IJ). Notably, the replies to the sets of questions (as shown in Table 1) were used individually to develop each of the RJ, DJ, PJ, and IJ indexes through the PCA. The answers are transformed, according to the following rules:

- in case of multiple-choice questions, a value is assigned that is equal to the total number of selected answer options. However, if the interest is in a specific answer option, 1 or 0 are assigned when the option is or is not ticked by the city (i.e., dummy variable);
- in case of single-choice questions, each answer option is weighted according to its value in terms of climate mitigation or justice awareness (i.e., it is transformed into a numeric categorical variable). However, when only one answer option is relevant to the formulation of the corresponding index, 1 or 0 are assigned when the option is or is not ticked by the city (i.e., dummy variable). Finally, when the answer is a number

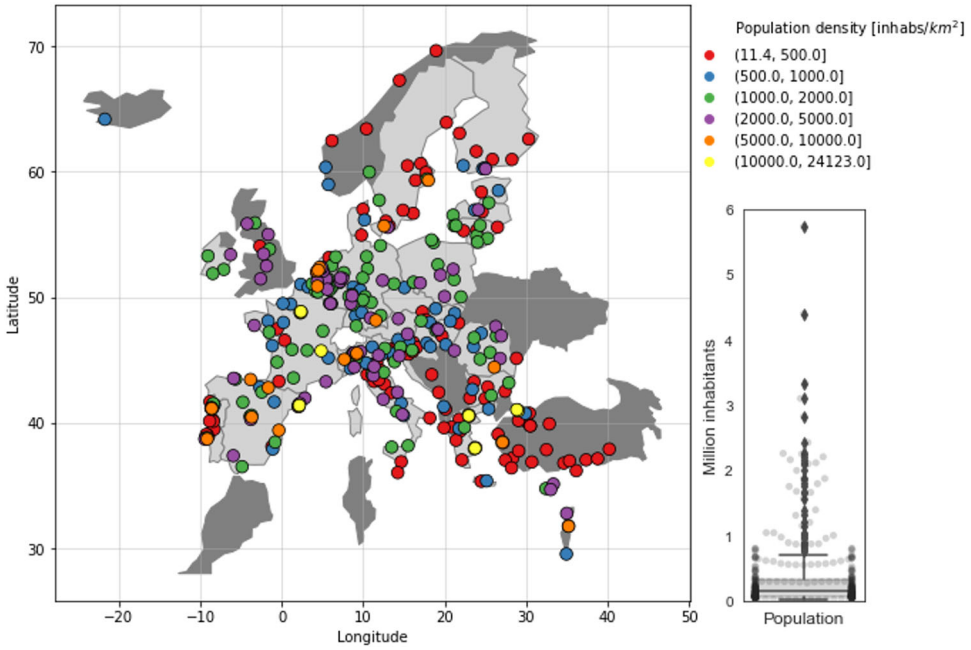

Fig. 1 Map of the surveyed cities (all those that agreed to publication are shown, i.e., 346 cities) and statistical distribution of city size. The colour code in the map is used to distinguish different groups by population density (population divided).

(e.g., the number of climate mitigation plans), no transformation is applied.

Table A.1 recalls the rules on a question-by-question basis and provides the original EOI questions.

The PCA was deemed as an appropriate method as it enables to (i) condense multiple variables that measure similar constructs into a smaller set of uncorrelated composite indexes, (ii) provide us with a concise set of indexes that allow for a more straightforward explanation of the relationships between the predictors (e.g., CE) and the outcome variable (i.e., CJA) while minimising information losses, and (iii) to handle multicollinearity, which can pose challenges in regression analysis (Shrestha, 2021). Therefore, the PCA fits well our study as we can derive indexes from multiple survey items and investigate the relationships between these indexes and other factors, while accounting for the potential challenges that might be encountered when condensing information (i.e., loss of information) and interpreting results (i.e., multicollinearity). This approach has also been used in previous similar studies that developed indexes related to engagement and awareness of energy issues (Martins et al., 2020).

Once derived the four justice indexes, we calculated the CJA index as a simple average of the four indexes, as we assumed that awareness of each of the four justice pillars has an equal weight in terms of contribution to the overall climate justice awareness. Therefore,

$$\mathrm{CJA} = \frac{RJ + DJ + PJ + IJ}{4} \quad (1)$$

The sixth index—the *climate engagement* (CE) index—was developed via PCA to capture cities' efforts in climate action. The selected questions to develop this index tried to capture the effort in sector-specific climate mitigation strategies and initiatives, as well as in their GHG emissions reduction targets.

After creating all the indexes, a simple ordinary least squares (OLS) regression was conducted to measure the explanatory power of the CE index and city-specific factors (population density, GDP per capita, favourable conditions, legal powers, barriers identified, and government support) on CJA (for more details on the city-specific factors, see Table A.2 in the Supplementary Appendix). As we are analysing survey data and aim to investigate quantitative relationships, the OLS regression model was deemed as the appropriate method, since it allows for the examination of the magnitude and direction of the relationships between the CJA (dependent variable) and the predictor variables (CE and city-specific factors). Additionally, by enabling quantitative estimates of these relationships, it allows for numerical comparisons and for policy recommendations (Wooldridge, 2015).

All analyses were performed using Stata 15.

Results

As described in the methods, the four justice pillar indexes and the CE index were developed via PCA (see Table A.3 in the Supplementary Appendix for details on the PCA output, such as communalities, total variance explained, and component matrix). The quality of the produced indexes is inferred by applying two well-established tests (Shrestha, 2021): the Kaiser–Meyer–Olkin (KMO) Measure of Sampling Adequacy and the Bartlett's test. The first test returns the proportion of variance in the variables that might be caused by underlying factors. When KMO values are higher than 0.5, the sample is deemed acceptable (Martins et al., 2020). The second test checks the hypothesis that the correlation matrix is an identity matrix, and indicates whether the variables are unrelated and not suitable for structure detection. When the output is less than 0.05, the available data is deemed suitable to apply the factor analysis.

The Bartlett's test reveals that the indexes are adequate, as all output values are below 0.05. The KMO corroborates the result, with all values higher than 0.5 (see Table 2). These results confirm that the developed indexes are suitable for the analysis.

Overall, across the 362 cities, the RJ index ranges within (−1.59, 6.17) with mean −1.96 (s.d. 2.17); the PJ index ranges within (−5.98, 5.27) with mean 2.36 (s.d. 2.32); the DJ ranges within (−2.41–8.78) with mean −2.54 (s.d. 2.99); and the IJ index ranges within (−1.20, 2.82) with mean 2.38 (s.d. 1.23). The CJA index across the 362 cities ranges within (−2.79, 5.76) with mean

Table 1 Selected questions.

Procedural justice	Distributive justice	Recognition justice	Intergenerational justice	Climate engagement
1. Assessed transparency and accountability	1. Assessed congestion	1. Assessed social inclusion, equality and justice impacts	1. Assessed natural resource depletion	1. Number of current energy policy measures
2. Assessed education and public awareness	2. Assessed labour conditions	2. Assessed energy poverty	2. Assessed biodiversity and ecosystem services	2. Number of current transport policy measures
3. Engaged citizen and renewable energy communities	3. Assessed energy security	3. Assessed security/protection for poor/vulnerable populations	3. Engaged youth & education sector	3. Number of current waste/ wastewater policy measures
4. Engaged academia/Research & Innovation (R&I) institutions	4. Assessed economic production	4. Assessed number of households and businesses forced from homes/places of work		4. Number of elements implemented in smart city solutions
5. Engaged citizens	5. Assessed revenue generation	5. Assessed premature deaths		5. Number of key measures
6. Engaged trade unions	6. Assessed costs	6. Assessed health impacts from extreme heat or cold weather		6. Number of R&I projects
7. Engaged vulnerable groups	7. Assessed business/technological innovation	7. Assessed mental wellbeing/quality of life		7. Number of initiatives
8. Engaged neighbouring local/regional government	8. Assessed job creation	8. Assessed resilience to climate change/ adaptation		8. Number of awards
9. Engaged NGOs and associations	9. Assessed economic impact of disasters	9. Addressed social aspects in plans		9. Climate neutrality geographic boundary
10. Implemented informative practices and awareness-raising events	10. Assessed disruption of energy, transport, water, and communications networks			10. Emissions reduction target for the future
11. Implemented educational activities and programmes	11. Assessed mobility and access			11. Geographic boundary of future target
12. Implemented deliberative practices	12. Assessed transport poverty			12. Consumption from RES
13. Implemented participatory budgeting to prioritise actions	13. Assessed water security			13. Generation from RES
14. Implemented ad-hoc co-creation engagement practices	14. Assessed food security			14. Collaborations with other cities
15. Implemented participatory urban planning	15. Assessed health costs			15. Duration of climate governance
16. Implemented nudges	16. Assessed air quality			16. Regular data collection-energy
17. Implemented workshops	17. Assessed water/soil quality			17. Regular data collection-transport
18. Implemented info points	18. Assessed light pollution			18. Regular data collection-waste/ wastewater
19. Implemented awareness-raising campaigns	19. Assessed noise pollution			
20. Implemented One Stop Shops	20. Assessed green space coverage and quality			
21. Promoted/used crowdfunding schemes	21. Used social impact bonds			
22. Created partnerships in data collection with citizens				
23. Created partnerships in data collection with trade unions				
24. Created partnerships in data collection with academia/R&I institutions				
25. Created partnerships in data collection with NGOs and associations				

HUMANITIES AND SOCIAL SCIENCES COMMUNICATIONS | https://doi.org/10.1057/s41599-023-01953-y

Table 2 Preliminary tests on the suitability of the indexes.

	intergenerational justice	recognition justice	distributive justice	procedural justice	climate engagement
Bartlett test of sphericity (Null hypothesis: variables are not intercorrelated)					
Chi-square	85.406	1715.167	3965.286	1808.422	2957.301
p-value	0.000	0.000	0.000	0.000	0.000
Kaiser–Meyer–Olkin measure of Sampling Adequacy (KMO)					
KMO	0.543	0.852	0.929	0.845	0.884

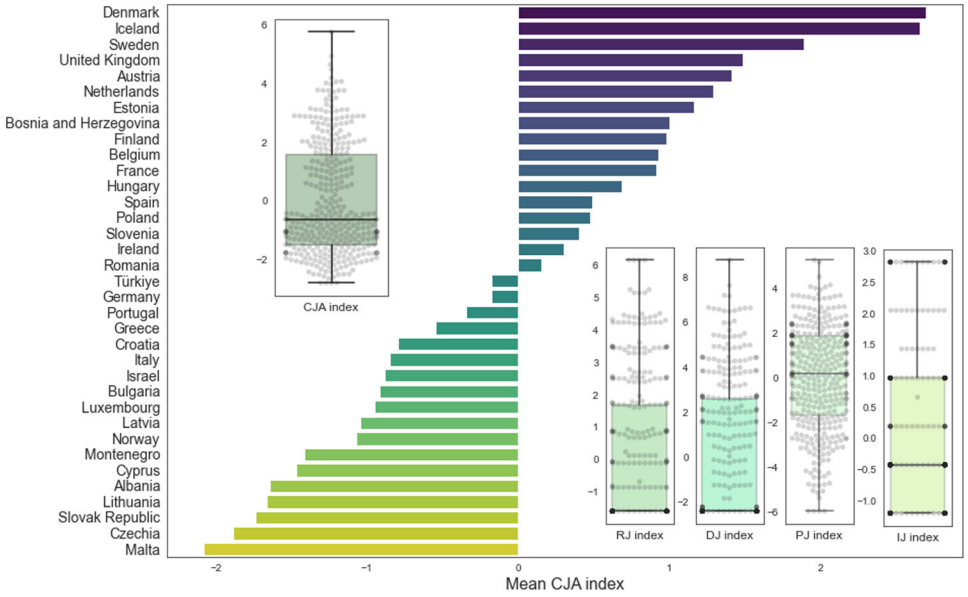

Fig. 2 CJA index distribution. Mean CJA index by country and statistical distribution of CJA and all its compositional indexes.

−6.02 (s.d. 1.88). The distribution can be visualised in Fig. 2. As shown in Fig. 2, this index seems to vary significantly across countries, on average.

To exclude issues of multicollinearity between the independent variables and the developed CJA index that we will use in the regression analysis, we assess the Pearson' correlation.

Table 3 shows that the values are not high enough to be concerned with multicollinearity, as all independent variables have an absolute value of Pearson correlation coefficient that is less than 0.5 (Young, 2018). This result is further corroborated by a second test for multicollinearity using the *variance inflation factor*, developed post-regression.

Table 3 also suggests the existence of a significant and strong correlation between CJA and:

i. CE (+)
ii. Log GDP per capita[1] (+),
iii. financial government support (+),
iv. reporting government support (+),
v. coordination government support (+),
vi. technical government support (+),
vii. tools and skills access government support (+),
viii. dissemination government support (+),
ix. capacity government support (+),
x. regulation government support (+),
xi. financial advisory government support (+),
xii. perceived favourable economy (+),
xiii. perceived favourable authorisation process (+),
xiv. perceived favourable financing (+),
xv. perceived favourable communication (+),
xvi. number of fields with legal power (+),
xvii. and number of identified barriers (+).

CJA is also mildly correlated with population density (+). The regression analysis is used to confirm the strength of such relationships.

Figure 3 shows the positive relationship suggested by the Pearson's correlation between climate engagement and climate awareness. It also shows that the average of the two indexes differs quite substantially across countries. Therefore, we first conduct the analysis using the whole dataset.

To ensure that we consider the relationships between cities within a country and take into account the shared characteristics among cities, we used cluster-robust standard errors. This method allows for a more comprehensive understanding of the correlation structure among cities within the same country and, thus, a more valid and robust approach than standard errors that assume independence among observations (in traditional statistical models that do not consider clustering, standard errors are assumed to be independent across all observations). However, in the context of cities within a country, this assumption may not hold true due to similarities arising from various factors such as geographical proximity, cultural influences, or policy interventions. Hence, we treat countries as clusters, recognising that cities within a country may have similar unobservable factors (Angrist & Pischke, 2008).

Second, to absorb any country effect and allow the estimates of the coefficients on city-level characteristics to differ across countries, we would ideally run a separate regression model for each country (Bryan & Jenkins, 2021). However, given that countries are unevenly represented in the pool of 362 Mission

Table 3 Pearson's correlation.

	CE	log GDP per capita	Population density	Government financial support	Government support to reporting	Government support to coordination	Government technical assistance	Government support to tools and skills	Government dissemination assistance	Government capacity building assistance	Government policy regulation assistance	Government financial advisory services	Favourable economy	Favourable funding & financing	Favourable communication	Favourable climate	Fields power count	Barriers count	CJA
CE	1																		
log GDP per capita	0.224*** (0)	1																	
Population density	0.0783 (−0.137)	0.0372 (−0.48)	1																
Government financial support	0.361*** (0)	0.0397 (−0.452)	−0.0355 (−0.5)	1															
Government support to reporting	0.291*** (0)	0.0247 (−0.64)	−0.0209 (−0.692)	0.261*** (0)	1														
Government support to coordination	0.203*** (0)	0.0381 (−0.47)	0.0881 (−0.094)	0.110* (−0.036)	0.326*** (0)	1													
Government technical assistance	0.278*** (0)	0.0611 (−0.246)	0.0151 (−0.775)	0.231*** (0)	0.396*** (0)	0.414*** (0)	1												
Government support to tools and skills	0.300*** (0)	0.0918 (−0.081)	−0.0276 (−0.601)	0.197*** (0)	0.383*** (0)	0.343*** (0)	0.430*** (0)	1											
Government dissemination assistance	0.309*** (0)	0.0794 (−0.132)	−0.0487 (−0.356)	0.292*** (0)	0.388*** (0)	0.234*** (0)	0.384*** (0)	0.284*** (0)	1										
Government capacity building assistance	0.317*** (0)	0.0656 (−0.213)	−0.0268 (−0.611)	0.225*** (0)	0.292*** (0)	0.276*** (0)	0.350*** (0)	0.397*** (0)	0.296*** (0)	1									
Government policy regulation assistance	0.183*** (0)	−0.0512 (−0.331)	−0.0353 (−0.503)	0.268*** (0)	0.229*** (0)	0.136** (0)	0.172** (0)	0.196*** (0)	0.177*** (0)	0.252*** (0)	1								
Government financial advisory services	0.270*** (0)	0.00398 (−0.94)	−0.00607 (−0.908)	0.210*** (0)	0.359*** (0)	0.286*** (0)	0.396*** (0)	0.397*** (0)	0.273*** (0)	0.381*** (0)	0.267*** (0)	1							
Favourable economy	0.355*** (0)	0.129* (−0.014)	0.0644 (−0.221)	0.0846 (−0.108)	0.0314 (−0.552)	0.083 (−0.115)	0.084 (−0.111)	0.125* (−0.017)	0.117* (−0.025)	0.0582 (−0.269)	0.0331 (−0.531)	0.0765 8-0.147)	1						
Favourable funding & financing	0.317*** (0)	−0.0565 (−0.283)	−0.00251 (−0.962)	0.256*** (0)	0.156** (−0.003)	0.044 (−0.404)	0.211*** (0)	0.178*** (−0.001)	0.168** (−0.001)	0.200*** (0)	0.117* (−0.026)	0.161** (−0.002)	0.443*** (0)	1					
Favourable communication	0.345*** (0)	0.033 (−0.531)	0.0539 (−0.306)	0.200*** (0)	0.222*** 0)	0.129* (−0.014)	0.213*** 0)	0.138** (−0.009)	0.262*** 0)	0.189*** 0)	0.109* (−0.037)	0.210*** 0)	0.296*** 0)	0.442*** 0)	1				
Favourable climate	0.0884 (−0.093)	−0.0811 (−0.123)	−0.0868 (−0.099)	0.0868 (−0.099)	0.0936 (−0.075)	0.0291 (−0.581)	0.0984 (−0.061)	0.0813 (−0.123)	0.046 (−0.383)	0.0907 (−0.085)	0.0702 (−0.182)	0.126* (−0.016)	0.317*** (0)	0.368*** (0)	0.271*** (0)	1			
Fields power count	0.482*** (0)	0.170** (−0.001)	−0.00933 (−0.86)	0.250*** (0)	0.185*** (0)	0.123* (0)	0.185*** (0)	0.321*** (0)	0.212*** (0)	0.237*** (0)	0.166** (−0.001)	0.221*** (0)	0.272*** (0)	0.282*** (0)	0.232*** (0)	0.148** (−0.005)	1		
Barriers count	0.200*** (0)	0.0495 (−0.348)	−0.0339 (−0.52)	0.176*** (−0.0019	0.0808 (−0.125)	0.0979 (−0.063)	0.0487 (−0.356)	0.0776 (−0.141)	0.118* (−0.024)	0.114* (−0.03)	0.074 (−0.16)	0.00767 (−0.884)	0.162** (−0.002)	0.140** (−0.008)	0.155** (−0.003)	0.222*** (0)	0.231*** (0)	1	
CJA	0.691*** (0)	0.199*** (0)	0.108* (−0.041)	0.284*** (0)	0.261*** (0)	0.228*** (0)	0.271*** (0)	0.258*** (0)	0.283*** (0)	0.345*** (0)	0.181*** (−0.001)	0.292*** (0)	0.213*** (0)	0.181*** (−0.001)	0.235*** (0)	−0.0249 (−0.637)	0.414*** (0)	0.152** (−0.004)	1

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, p-values in parentheses.

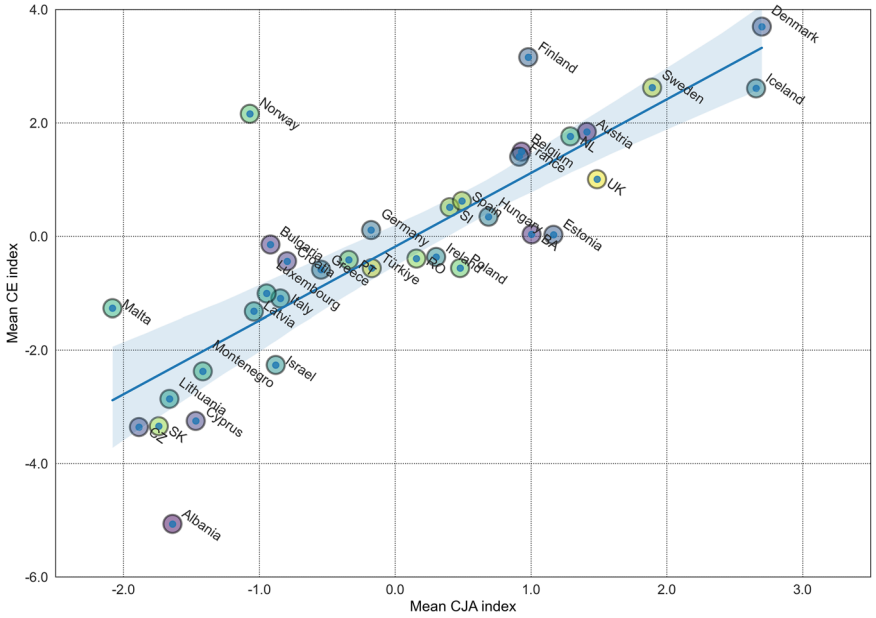

Fig. 3 Climate awareness and climate engagement: average indexes by country. Some country names have been replaced with their official codes (Eurostat, 2023) for better visibility.

cities, we resort to the category-based approach in which regressions are computed separately on three country categories based on geographical attributes:

- **Eastern**: Poland, Lithuania, Latvia, Estonia, Belarus, Ukraine, Moldova, Romania, Bulgaria, Montenegro, Macedonia, Albania, Kosovo, Croatia, Slovenia, Czech Republic, and Slovakia.
- **North-Western**[2]**:** Finland, Sweden, Denmark, Norway, Iceland, France, Austria, Switzerland, Germany, Belgium, Netherlands, Luxembourg, Ireland, and the UK.
- **Southern**: Spain, Portugal, Malta, Italy, Greece, Cyprus, Turkey, and Israel.

Table 4 and Fig. 4 show the general model considering the whole sample of cities and a category-based approach in which regressions are conducted based on countries' categories. Results confirm a positive correlation between climate engagement and climate justice awareness.

Across all models, we find that high climate engagement seems to have a positive influence on the potential that climate decisions are made in a justice-aware way, as the two indexes result correlated regardless of the country group.

When looking at the general model, we also find that the justice-awareness potential is positively influenced by the availability of governmental support in capacity building and in financial advisory services, and by the breadth of the fields over which the city has legal power to act/make policy decisions. Conversely, it is negatively influenced by the perception that the city geo-climatic conditions are favourable (e.g., proximity to water bodies, moderate occurrence of climate extremes).

In North-western cities, justice awareness is positively influenced by the availability of government support in coordination and by the density of population, whereas in Southern cities, by the extent of the city legal powers and by the availability of governmental support in financial advisory services, resource mobilisation and reporting. In Eastern cities, higher justice awareness comes with the availability of governmental support in capacity building and in financial support, and project development/implementation. Conversely, it is negatively influenced by the perception of a favourable climate and financial situation.

Overall, all models seem to be satisfactory in explaining variability, as all R^2 are above 0.5, and in avoiding multicollinearity, as the mean VIF is always between 1 and 5, indicating moderate correlation between the other explanatory variables in the model, but not severe enough to require attention.

Discussion

Correlation analysis was conducted to examine the associations between CJA and potential drivers and barriers affecting just climate action development in a large sample of European cities. At this stage, the focus was on identifying general influences. Out of the 18 factors tested, 17 were found to be significantly related to both climate engagement and city-specific factors.

CE exhibits a strong positive correlation ($p < 0.01$). This result suggests that the more cities exert efforts in addressing climate change goals, the more they are likely to take climate justice concerns on board when designing and implementing climate efforts. The following city-specific institutional and socio-economic factors were identified as the most influential drivers of justice-awareness potential, exhibiting strong positive correlations ($p < 0.01$):

- GDP per capita and degree of city legal powers;
- government (i) financial support, (ii) reporting support, (iii) coordination support, (iv) technical assistance, (v) skill support, (vi) dissemination assistance, (vii) capacity building assistance, (viii) policy regulation assistance, (ix) financial advisory services;
- perceptions of a favourable (i) economy, (ii) financial situation, (iii) communication, and
- identified barriers to climate action.

These results suggest that wealthier cities could more likely attain social justice goals when planning and implementing climate action. Cities that consider their economic, financing, and communication strategies as favourable city-specific features are also more likely to be climate justice aware. Results also suggest that cities that receive cross-sectoral support from higher governance levels are more likely to take into account justice

Table 4 Regression analyses.

	(All)	(North West)	(South)	(East)
Variables	**CJA**	**CJA**	**CJA**	**CJA**
CE	0.420***	0.526***	0.350***	0.413***
	(0.0362)	(0.0738)	(0.0657)	(0.0566)
log GDP per capita	0.0649	−0.120	0.198	−0.121
	(0.0859)	(0.168)	(0.126)	(0.122)
Population density	0.0000317	0.0000880**	0.0000192	−0.00000831
	(0.0000225)	(0.0000349)	(0.0000187)	(0.0000995)
Government Financial Support	0.0524	0.163	−0.183	0.637***
	(0.211)	(0.427)	(0.315)	(0.190)
Government Support to Reporting	0.0440	−0.179	0.521*	−0.301
	(0.168)	(0.181)	(0.251)	(0.406)
Government Support to Coordination	0.145	0.662**	−0.00296	−0.323
	(0.142)	(0.228)	(0.200)	(0.209)
Government Technical Assistance	0.0986	−0.0585	−0.102	0.0725
	(0.179)	(0.364)	(0.229)	(0.366)
Government Support to tools and skills	−0.185	−0.114	−0.377	0.310
	(0.218)	(0.410)	(0.264)	(0.475)
Government Dissemination Assistance	0.0967	0.324	0.0135	0.0664
	(0.157)	(0.329)	(0.266)	(0.270)
Government Capacity Building Assistance	0.405***	0.345	0.273	0.938**
	(0.148)	(0.343)	(0.181)	(0.355)
Government policy Regulation Assistance	0.0717	−0.0205	0.0400	0.321
	(0.161)	(0.177)	(0.244)	(0.480)
Government Financial Advisory services	0.297*	0.457	0.642***	−0.307
	(0.152)	(0.267)	(0.149)	(0.368)
Favourable economy	0.00525	0.0104	−0.0430	0.0295
	(0.0588)	(0.110)	(0.121)	(0.121)
Favourable funding & financing	−0.0743	−0.0204	0.000224	−0.340*
	(0.0865)	(0.129)	(0.154)	(0.161)
Favourable communication	−0.00893	−0.116	0.0402	0.0926
	(0.0628)	(0.140)	(0.0964)	(0.0903)
Favourable climate	−0.164**	−0.166	−0.142	−0.183**
	(0.0708)	(0.113)	(0.101)	(0.0843)
Fields power count	0.0541**	0.00146	0.112***	−0.0229
	(0.0264)	(0.0495)	(0.0225)	(0.0347)
Barriers count	0.0301	0.0339	0.0604	−0.0594
	(0.0550)	(0.142)	(0.0653)	(0.111)
Constant	−1.134	1.037	−3.249***	1.817
	(0.948)	(1.736)	(0.620)	(1.572)
Observations	362	130	147	85
VIF	1.40	1.50	1.58	1.55
R-squared	0.528	0.524	0.537	0.609

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$, Standard errors clustered at country level.

dimensions. Two key drivers of CJA are also the breadth of cities legal power and the ability to identify more barriers to climate action. Population size exhibits only a mild positive correlation ($p < 0.10$). This suggests that being a populous city might not necessarily lead to more justice considerations when developing climate action. Finally, perceiving climate as a favourable city-specific feature does not seem to be a motivating factor for cities to take into account justice dimensions in climate efforts.

The above correlation results are only partially confirmed by the regression analysis conducted on the whole sample of cities. Using all factors analysed in the correlation matrix yields a model of moderate good fit. In particular, the R^2 of 0.529 indicates that the model explains a substantial portion of the variability in the CJA index. For CJA, CE and receiving government financial support are important factors with a strongly significant ($p < 0.01$) contribution to the model. Notably, the coefficient of 0.420 suggests a positive and statistically significant relationship between CE and CJA, wherein a one-unit increase in CE is associated with an estimated increase of 0.420 units in CJA, assuming all other variables in the model are held constant. This implies that cities that are more engaged in climate action tend to show higher levels of CJA. The coefficient of 0.405 suggests a positive and statistically significant relationship between CJA and government financial support, wherein a one-unit increase in government financial support is associated with an estimated increase of 0.405 units in CJA, ceteris paribus. This implies that cities that receive more financial support from higher governance levels tend to show higher levels of CJA. The breadth of legal power and perceiving climate as a city-specific favourable condition are also important influencing factors of CJA, but with a lesser significance extent ($p < 0.05$). The coefficient of 0.0541 suggests a positive and statistically significant relationship between number of fields with legal power and CJA, wherein a one-unit increase in the number of fields with legal power is associated with an estimated increase of 0.0541 units in CJA, ceteris paribus. This implies that cities that have the power to take decisions on a breadth of climate-related fields tend to show higher levels of CJA. The coefficient of −0.164 suggests a negative and statistically significant relationship between favourable climate perceptions and CJA, wherein a one-unit

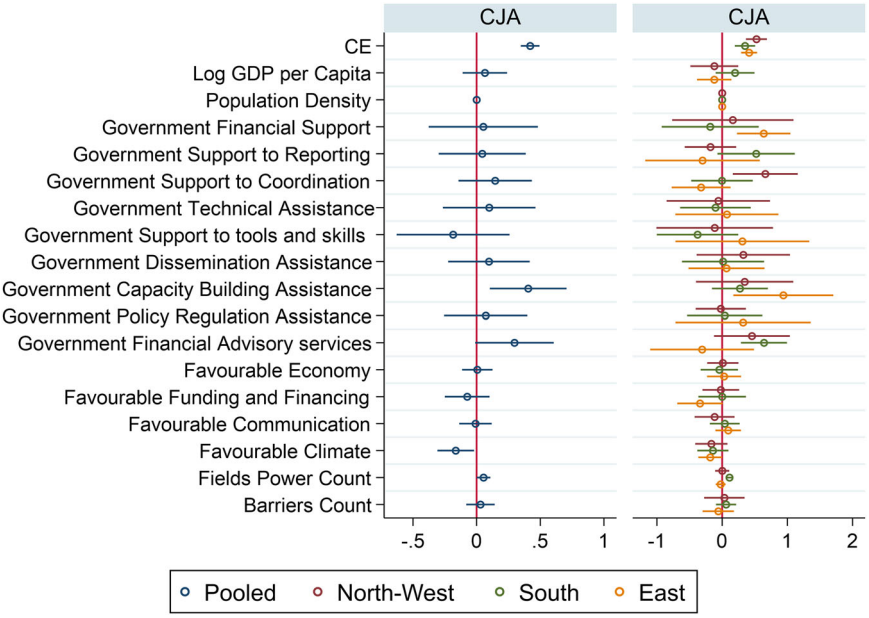

Fig. 4 Regression coefficients. Coefficients estimates and confidence intervals from regression models analysing i) all cities (blue) ii) North-Western cities (red), iii) Southern cities (green), and iv) Eastern cities (yellow).

increase in favourable climate perceptions is associated with an estimated decrease of 0.164 units in CJA, ceteris paribus. This implies that cities that do not perceive the urgency to act on their local climate tend to show lower levels of CJA. Finally, receiving financial advisory services from the government only mildly explains CJA. The coefficient of 0.297 suggests a positive and statistically significant ($p < 0.10$) relationship between financial advisory services and CJA, wherein a one-unit increase in available financial advisory services is associated with an estimated increase of 0.297 units in CJA, assuming all other variables in the model are held constant. This implies that cities that are equipped with more government financial advisory services tend to show higher levels of CJA.

Overall, results from the general regression model suggest that CE has a positive impact on cities' climate justice awareness, irrespective of their geographical classification. They also suggest that the availability of governmental support in capacity building and financial advisory services, and the extent of the city legal powers across different fields of action are positively related to justice awareness. This suggests that when cities have the means and freedom to decide how to plan and implement climate efforts, they can also pursue objectives that are not immediately related to emission reduction, but embrace a broader dimension sensitive to social justice. At the same time, results suggest that the perception of favourable geo-climatic conditions is negatively related to climate justice awareness. This insight further echoes the positive relationship between CE and CJA, as a favourable climate might reduce the perceived urgency of climate action and the consideration of the social issues associated with it.

The results from the regression analyses run on specific geographic groups highlight that when country effects are taken into account, the relationships with CJA estimated with the general model are not always confirmed. Additionally, they unveil relationships with new dimensions. This suggests that aggregating data can make certain relationships only apparently strong (Wooldridge, 2015), and that the fact that cities within the same geographic region might share similar governance structures, historical legacies, and economic, cultural, and political characteristics (Breil et al., 2018) needs to be accounted in the analysis.

For all geographical groups, the regression model yields a moderate good fit since the R^2 (0.524 for North-Western cities, 0.537 for Southern cities, and 0.609 for Eastern cities) indicates that the model explains a substantial portion of the variability in the CJA index. As observed in the general model, we find that for CJA, CE is a key factor with a strongly significant ($p < 0.01$) contribution to the model, with the following territorial nuances. The coefficients (0.526, 0.350, and 0.413 for the three groups respectively) suggest a positive and statistically significant relationship between CE and CJA, wherein a one-unit increase in CE is associated with an estimated increase of 0.526, 0.350, and 0.413 units in CJA (and thus 0.106 more or 0.07 and 0.007 units less than estimated in the general model, respectively).

When it comes to North-Western cities in particular, differently from the general model we find that population density and receiving coordination support from the government moderately ($p < 0.05$) explain CJA. Notably, the coefficient of 0.0000880 suggests a positive and statistically significant relationship between population density and CJA, wherein a one-unit increase in population density is associated with an estimated increase of 0.0000880 units in CJA. This implies that densely populated North-Western cities tend to show higher levels of CJA. Further, the coefficient of 0.662 suggests a positive and statistically significant relationship between receiving coordination support from the government and CJA, wherein a one-unit increase in government coordination support is associated with an estimated increase of 0.662 units in CJA. This entails that North-Western cities that receive higher coordination support from the government tend to show higher levels of CJA. Overall, the regression analysis for North-western cities reveals that CJA is positively influenced by the availability of governmental support in coordination and by population density. This suggests that the provision of support in coordination can be a key way to address the potential high structural complexity (level of alignment and interaction across different governance and low population density) undermining the attention North-western cities can devote to social objectives when planning and implementing climate action. This finding aligns with existing evidence on the higher emissions mitigation ambition demonstrated by Northern and Western Europe cities (Reckien et al., 2018; Reckien et al., 2015;

Salvia et al., 2021) and with the significant correlation between such ambition and national incentives, characteristics, and climate policies (Hsu et al., 2020; Salvia et al., 2021).

Similar to the general model, among Southern cities, receiving financial advisory services from the government and the breadth of legal power explain CJA, and these relationships are stronger ($p < 0.01$) than for the general model. The coefficient of 0.642 suggests that a one-unit increase in available financial advisory services is associated with an estimated increase of 0.642 units in CJA, ceteris paribus. This implies that Southern cities that are equipped with more government financial advisory services tend to show higher levels of CJA. The coefficient of 0.112 suggests that a one-unit increase in the number of fields with legal power is associated with an estimated increase of 0.112 units in CJA, ceteris paribus. This implies that the more Southern cities have the power to decide where to exert their climate effort, the more they tend to show higher levels of CJA. Finally, differently from the general model, we find that receiving government support on reporting moderately ($p < 0.10$) explains CJA. Notably, the coefficient of 0.521 suggests a positive and statistically significant relationship between government support on reporting and CJA, wherein a one-unit increase in government support on reporting is associated with an estimated increase of 0.521 units in CJA. This entails that Southern cities that are equipped with tools that ease coordination tend to show higher levels of CJA. Overall, for Southern cities, results highlight that CJA is positively influenced by the breadth of the city legal powers and by the availability of governmental support in financial advice and resource mobilisation, and mildly in reporting. This suggests that providing more legitimacy and advice on how to get resources for climate action by higher-level governments can be a key way to make Southern cities more considerate of social objectives in their climate efforts.

Finally, for Eastern cities and in agreement with the general model, we find that perceiving own climate as a favourable local feature explains CJA, and this relationship is stronger ($p < 0.05$) than for the general model. The coefficient of −0.183 suggests that a one-unit increase in perceptions of a favourable climate is associated with an estimated decrease of 0.183 units in CJA, ceteris paribus. This implies that Eastern cities that perceive a lesser urgency to act on their local climate tend to show lower levels of CJA. Further, differently from the general model, we find that receiving government financial support strongly ($p < 0.01$) explains CJA, and perceiving financial conditions as favourable local features moderately ($p < 0.10$) does so. The coefficient of 0.637 suggests that a one-unit increase in government financial support is associated with an estimated increase of 0.637 units in CJA, ceteris paribus. This entails that Eastern cities that receive financial support are more prone to consider justice dimensions. The coefficient of −0.340 suggests that a one-unit increase in perceptions of favourable financial conditions is associated with an estimated decrease of 0.340 units in CJA, ceteris paribus. This complements the previous result, suggesting that cities that are eligible for financial support are more prone to consider justice dimensions. Overall, the regression analysis on Eastern cities reveals that climate justice awareness is positively influenced by the availability of governmental support in capacity building, financial support, and project development/implementation, while it is negatively influenced by the perception of a favourable climate and mildly, financial situation. This suggests that equipping Eastern cities with additional means and resources can be a key way to ease the consideration of justice dimensions. Conversely, the result that cities get socially detached when feeling secure (in terms of climate and financial risks) points to a need to address security misperceptions and empowerment. Indeed, there is evidence that Southern and Eastern cities—particularly those ranking low in terms of capacity/GDP—tend to be less ambitious in climate mitigation and to rely on exogenous systems (international climate networks, national government) to steer their climate action (Salvia et al., 2021). This may entail that for these cities, external forces define their capacity to co-tackle climate justice.

With respect to policy implications, in Northern cities, where economic development and low population density might increase the complexity of decision-making, support in coordination might ease the consideration of social objectives in climate action. Being more advanced in their adaptation policies, and having a longer tradition of citizen engagement (Breil et al., 2018), most North-western cities are focused on abating the hardest emissions (i.e., the last percentage points), hence a high degree of coordination needs to be in place to remove residual barriers (e.g., complex jurisdictions, unfavourable regulations). Southern cities, which are at higher risks from negative social and environmental consequences of climate change (Mavromatidi et al., 2018), reveal a good potential to implement a social just climate action, but this needs to be unlocked through empowerment measures. In Eastern cities, where paths defined by institutional and historical legacies might still dictate an infrastructural and economic divide (Ürge-Vorsatz et al., 2018), more immediate objectives might take over the consideration of social objectives, unless cities receive dedicated external support.

Conclusions

Cities can be key agents of change in addressing global climate change, being "natural" sites for innovative and experimental climate action in a progressive direction. Cities themselves acknowledged this role in Europe, as testified by the European Mission on 100 Climate-Neutral and Smart Cities, where 100+ cities committed to pursue climate neutrality by 2030. However, even among the most ambitious cities in climate mitigation, there might be considerable heterogeneity in the scope of climate action. In particular, cities can be loci of injustices, if they are not able to recognise how planned climate efforts might generate or exacerbate forms of injustice in their specific contexts. That is why, cities need to be justice-aware when developing climate action.

Climate justice has increasingly gained momentum in the academic and policy debates on climate change; however, many have also debated its operational value. The few investigations on the topic are based on a limited number of cities and interpretative indicators. The main contribution of this study lies in empirically uncovering the operational value of climate justice in urban climate action, by evaluating climate justice concerns in urban climate decision-making processes and by identifying key areas that could lead to better consideration of justice dimensions across European cities. We demonstrate, via econometric analysis, a way to homogenously evaluate the degree of justice awareness in climate action planning, and to use this measure as a lever to guide and course-correct city-level climate policy to simultaneously pursue the climate change and social justice goals.

Drawing from the climate justice framework and a unique dataset comprising responses homogenously elicited through a survey, we created an indicator for climate justice awareness and assessed how this can be predicted by climate engagement and a set of city-specific factors. In particular, we used the data from 362 cities who expressed interest in the Cities Mission, and used a PCA approach to develop a climate justice awareness index inclusive of the procedural, distributive, recognition, and intergenerational justice pillars.

Correlation and regression results reveal that, regardless of the geographical categorisation, cities' climate justice awareness is positively influenced by climate engagement. This empirical evidence,

new to the current literature, provides some implications for practice, as it shows that cities that are more engaged in addressing climate change goals tend to design and implement their efforts by co-targeting social justice goals. Moreover, our results offer additional novel insights into how some city-specific factors might act as drivers and barriers to justice-considerate climate action.

Overall and for the first time to the best of the authors' knowledge, this study sheds light on the positive relationship that exists between engagement in climate action at the city level and awareness of its social justice aspects, evaluated across its recognitional, distributive, procedural, and intergenerational dimensions. Embedding justice considerations into climate action planning implies additional challenges and a higher degree of integration and holism in urban planning and policy-making. This is mirrored in the predictors for higher justice awareness levels and is nuanced according to specific national characteristics. The insights gathered through this analysis constitute a solid baseline to improve our understanding of the drivers and barriers to a just climate transition. They can legitimate and inform ongoing climate mitigation frameworks at an international and European scale, such as the UN-backed Race to Zero campaign, that rally non-State actors to take rigorous and immediate action to reduce global emissions and deliver a healthier, fairer zero-carbon world in time. As engagement in climate efforts tends to co-stimulate social justice goals, ongoing and future climate agendas could capitalise on the results here presented to maximise the synergistic effect and to leverage the territorial, economic, and socio-political predictors.

However, it is important to note that correlation and regression analysis alone cannot establish causal relationships. Therefore, an avenue for future research is to undertake comprehensive analyses to delve deeper into the associations uncovered in this study. Future research could also involve exploring how each of the four climate justice pillars are understood by urban decision-makers and citizens by engaging in interviews with them. Such efforts would contribute to the development of comprehensive climate justice awareness indices that incorporate better the characteristics of cities. Finally, we analysed a particular subgroup of ambitious cities in climate action, at the stage of formulating a vision to climate neutrality in the short haul. Future studies should investigate the planned and implemented efforts of the 100+ selected cities, by assessing how climate justice is factually integrated in their actions. Furthermore, as the Cities Mission proceeds in its implementation phase, new knowledge and experience will be generated on how to deliver just transformations within and beyond the city boundary. A fully fledged just transition builds on values of territorial cohesion and multi-level governance to legitimise the target and multiply the benefits. Hence, best practices in multi-scale action and in tackling Scope 3/consumption-based emissions will be collected and guidelines will be disseminated through the Mission in the attempt to eradicate "low-carbon illusions" and establish a paradigm of full climate responsibility. As cities acknowledged in the EOI that non-compliance with the principle of equal opportunities on all levels throughout the transition will undermine its achievement, it is expected that the Mission will catalyse the conceptualisation, testing, and spread of new transition models to expand the frontiers of climate justice across local-to-global networks of production, consumption, and distribution.

Data availability

The datasets generated and analysed during the current study are not publicly available due to confidentiality agreements.

Received: 10 March 2023; Accepted: 18 July 2023;
Published online: 26 July 2023

Notes

1 We take the log of GDP per capita to reduce the right skewness of GDP per capita (values of GDP per capita are skewed around left tail). Another reason is that GDP per capita is better considered on a multiplicative rather than additive scale (€1000 is worth a lot more to a vulnerable than a rich because €1000 is a much greater fraction of the poor person's wealth)

2 Northern and Western cities have been pooled together as Northern cities were only 33; therefore, this number was not sufficient to conduct a separate regression model.

References

Angelo H, Wachsmuth D (2015) Urbanizing urban political ecology: a critique of methodological cityism. Int J Urban Region Res 39(1):16–27

Angelo H, Wachsmuth D (2020) Why does everyone think cities can save the planet? Urban Stud 57(11):2201–2221

Angrist JD, Pischke JS (2008) Mostly harmless econometrics: an empiricist's companion. In: Mostly harmless econometrics: an empiricist's companion. Princeton University Press

Anguelovski I, Shi L, Chu E, Gallagher D, Goh K, Lamb Z, Reeve K, Teicher H (2016) Equity impacts of urban land use planning for climate adaptation: critical perspectives from the global North and South. J Plann Educ Res 36(3). https://doi.org/10.1177/0739456X16645166

Bellucci F, Bogner JE, Sturchio NC (2012) Greenhouse gas emissions at the urban scale. Elements, 8(6). https://doi.org/10.2113/gselements.8.6.445

Bouzarovski S, Haarstad H (2019) Rescaling low-carbon transformations: towards a relational ontology. Trans Inst Br Geogr 44(2). https://doi.org/10.1111/tran.12275

Brand AL, Charles M (2020) Tomorrow I'll be at the table: Black geographies and urban planning: Areview of the literature. J Plan Lit 35(4):460–474

Breil M, Downing C, Kazmierczak A, Mäkinen K, Romanovska L, Terämä E, Swart RJ (2018) Social vulnerability to climate change in European cities–state of play in policy and Practice (ETC/CCA Technical Paper; No. 2018/1), EEA–European Environment Agency

Brisley R, Welstead J, Hindle R, Paavola J (2012) Socially just adaptation to climate change. Joseph Roundtree Foundation, York, UK

Bryan ML, Jenkins SP (2021) Regression analysis of country effects using multilevel data: a cautionary tale. SSRN Electron J. https://doi.org/10.2139/ssrn.2322088

Bulkeley H (2010) Cities and the governing of climate change. Ann Rev Environ Resour 35. https://doi.org/10.1146/annurev-environ-072809-101747

Castán Broto V, Westman LK (2020). Ten years after Copenhagen: reimagining climate change governance in urban areas. Wiley Interdiscip Rev Clim Change. 11(4). https://doi.org/10.1002/wcc.643

Chu EK, Cannon CE (2021) Equity, inclusion, and justice as criteria for decision-making on climate adaptation in cities. Curr Opin Environ Sustain. 51 https://doi.org/10.1016/j.cosust.2021.02.009

Colenbrander S, Dodman D, Mitlin D (2018) Using climate finance to advance climate justice: the politics and practice of channelling resources to the local level. Clim Policy, 18(7). https://doi.org/10.1080/14693062.2017.1388212

Della Valle N, Czako V (2022) Empowering energy citizenship among the energy poor. Energy Res Soc Sci 89(C):102654

Eriksen S, Schipper ELF, Scoville-Simonds M, Vincent K, Adam HN, Brooks N, Harding B, Khatri D, Lenaerts L, Liverman D, Mills-Novoa M, Mosberg M, Movik S, Muok B, Nightingale A, Ojha H, Sygna L, Taylor M, Vogel C, West JJ (2021) Adaptation interventions and their effect on vulnerability in developing countries: help, hindrance or irrelevance? World Dev 141. https://doi.org/10.1016/j.worlddev.2020.105383

Eurostat (2023) Statistics explained—glossary: country codes. Eurostat

Evans J, Karvonen A, Raven R (2016) The experimental city. Routledge

Evans JP (2011) Resilience, ecology and adaptation in the experimental city. Trans Inst Br Geogr 36(2). https://doi.org/10.1111/j.1475-5661.2010.00420.x

Fiack D, Cumberbatch J, Sutherland M, Zerphey N (2021) Sustainable adaptation: Social equity and local climate adaptation planning in U.S cities. Cities 115:103235. https://doi.org/10.1016/j.cities.2021.103235

Fitzgibbons J, Mitchell C (2019). Just urban futures? Exploring equity in "100 resilient cities." World Dev 122. https://doi.org/10.1016/j.worlddev.2019.06.021

Gonzalez-Ricoy I, Rey F (2019) Enfranchising the future: climate justice and the representation of future generations. Wiley Interdiscip Rev Clim Change. 10(5). https://doi.org/10.1002/wcc.598

Hoornweg D, Sugar L, Gómez CLT (2011) Cities and greenhouse gas emissions: moving forward. Environ Urban 23(1). https://doi.org/10.1177/0956247810392270

Hsu A, Tan J, Ng YM, Toh W, Vanda R, Goyal N (2020) Performance determinants show European cities are delivering on climate mitigation. Nat Clim Change 10(11):1015–1022. https://doi.org/10.1038/s41558-020-0879-9
Hughes S, Hoffmann M (2020) Just urban transitions: toward a research agenda. In: Wiley Interdiscip Rev Clim Change 11(3). https://doi.org/10.1002/wcc.640
Intergovernmental Panel on Climate Change (2015) Human settlements, infrastructure, and spatial planning. In: Climate Change 2014: Mitigation of Climate Change. Cambridge University Press
Juhola S, Heikkinen M, Pietilä T, Groundstroem F, Käyhkö J (2022) Connecting climate justice and adaptation planning: an adaptation justice index. Environ Sci Policy, 136. https://doi.org/10.1016/j.envsci.2022.07.024
Krause D (2021) Transformative approaches to address climate change and achieve climate justice. In: Routledge handbook of climate justice. Routledge
Lawrence P, Köhler L (2017) Representation of future generations through international climate litigation: a normative framework. German Yearbook of International Law, 60. https://doi.org/10.3790/gyil.60.1.639
Long J, Rice JL (2019) From sustainable urbanism to climate urbanism. Urban Stud 56(5). https://doi.org/10.1177/0042098018770846
Martins A, Madaleno M, Dias MF (2020). Energy literacy assessment among Portuguese university members: Knowledge, attitude, and behavior. Energy Rep 6. https://doi.org/10.1016/j.egyr.2020.11.117
Mavromatidi A, Briche E, Claeys C (2018). Mapping and analyzing socio-environmental vulnerability to coastal hazards induced by climate change: an application to coastal Mediterranean cities in France. Cities, 72. https://doi.org/10.1016/j.cities.2017.08.007
McCauley DA, Heffron RJ, Stephan H, Jenkins K (2013) Advancing energy justice: the triumvirate of tenets. Int Energy Law Rev 32(3):107–110
Meerow S, Newell JP (2019) Urban resilience for whom, what, when, where, and why? Urban Geogr 40(3). https://doi.org/10.1080/02723638.2016.1206395
Mundaca L, Busch H, Schwer S (2018) 'Successful' low-carbon energy transitions at the community level? An energy justice perspective. Appl Energy 218. https://doi.org/10.1016/j.apenergy.2018.02.146
Nevens F, Roorda C (2014). A climate of change: a transition approach for climate neutrality in the city of Ghent (Belgium). Sustain Cities Soc 10. https://doi.org/10.1016/j.scs.2013.06.001
Newell P, Srivastava S, Naess LO, Torres Contreras GA, Price R (2021) Toward transformative climate justice: an emerging research agenda. Wiley Interdiscip Rev Clim Change 12(6). https://doi.org/10.1002/wcc.733
Phillips J, Bouzarovski S, Boamah F, Fuller S, Furlong K, Knuth S, Mould I, Thomson H, Zheng W (2022) Just transitions in cities and regions: a global agenda. British Academy Working Paper
Reckien D, Salvia M, Heidrich O, Church JM, Pietrapertosa F, De Gregorio-Hurtado S, D'Alonzo V, Foley A, Simoes SG, Krkoška Lorencová E, Orru H, Orru K, Wejs A, Flacke J, Olazabal M, Geneletti D, Feliu E, Vasilie S, Nador C, Dawson R (2018) How are cities planning to respond to climate change? Assessment of local climate plans from 885 cities in the EU-28. J Clean Prod 191:207–219. https://doi.org/10.1016/j.jclepro.2018.03.220
Reckien Diana, Buzasi A, Olazabal M, Spyridaki N-A, Eckersley P, Simoes SG, Salvia M, Pietrapertosa F, Fokaides P, Goonesekera SM, Tardieu L, Balzan MV, de Boer CL, De Gregorio Hurtado S, Feliu E, Flamos A, Foley A, Geneletti D, Grafakos S, Wejs A (2023) Quality of urban climate adaptation plans over time. Npj Urban Sustain 3(1):13. https://doi.org/10.1038/s42949-023-00085-1
Reckien D, Flacke J, Olazabal M, Heidrich O (2015) The influence of drivers and barriers on urban adaptation and mitigation plans-an empirical analysis of European Cities. PLoS ONE 10(8). https://doi.org/10.1371/journal.pone.0135597
Roberts JT, Parks BC (2015) A climate of injustice: global inequality, north-south politics, and climate policy. In: Global environmental accord (vol. 1). The MIT Press
Salvia M, Reckien D, Pietrapertosa F, Eckersley P, Spyridaki NA, Krook-Riekkola A, Olazabal M, De Gregorio Hurtado S, Simoes SG, Geneletti D, Viguié V, Fokaides PA, Ioannou BI, Flamos A, Csete MS, Buzasi A, Orru H, de Boer C, Foley A, … Heidrich O (2021). Will climate mitigation ambitions lead to carbon neutrality? An analysis of the local-level plans of 327 cities in the EU. Renew Sustain Energy Rev 135. https://doi.org/10.1016/j.rser.2020.110253
Sanson AV, Burke SEL (2020). Climate change and children: an issue of intergenerational justice. In: Children and peace. Springer https://doi.org/10.1007/978-3-030-22176-8_21
Schlosberg D (2004) Reconceiving environmental justice: global movements and political theories. Environ Polit 13(3). https://doi.org/10.1080/0964401042000229025
Schlosberg D, Collins LB (2014). From environmental to climate justice: climate change and the discourse of environmental justice. Wiley Interdiscip Rev Clim Change 5(3). https://doi.org/10.1002/wcc.275
Shi L, Chu E, Anguelovski I, Aylett A, Debats J, Goh K, Schenk T, Seto KC, Dodman D, Roberts D, Roberts JT, Van Deveer SD (2016) Roadmap towards justice in urban climate adaptation research. Nat Clim Change 6(2). https://doi.org/10.1038/nclimate2841
Shrestha N (2021) Factor analysis as a tool for survey analysis. Am J Appl Math Stat 9(1). https://doi.org/10.12691/ajams-9-1-2
Sovacool BK, Burke M, Baker L, Kotikalapudi CK, Wlokas H (2017) New frontiers and conceptual frameworks for energy justice. Energy Policy 105:677–691
Sovacool BK, Dworkin MH (2014) Global energy justice: problems, principles, and practices. Cambridge University Press
Sovacool BK, Dworkin MH (2015) Energy justice: {Conceptual} insights and practical applications. Appl Energy 142:435–444
Ulpiani G, Vetters N, Melica G, Bertoldi P (2023). Towards the first cohort of climate-neutral cities: expected impact, current gaps, and next steps to take to establish evidence-based zero-emission urban futures. Sustain Cities Soc 95(104572). https://doi.org/10.1016/j.scs.2023.104572
United Nations (2019) World urbanization prospects - population division. In United Nations
Ürge-Vorsatz D, Rosenzweig C, Dawson RJ, Sanchez Rodriguez R, Bai X, Barau AS, Seto KC, Dhakal S (2018) Locking in positive climate responses in cities. Nat Clim Change 8(3):174–177
van der Heijden J, Patterson J, Juhola S, Wolfram M (2019). Special section: advancing the role of cities in climate governance–promise, limits, politics. J Environ Plann Manage 62(3). https://doi.org/10.1080/09640568.2018.1513832
Wachsmuth D, Cohen DA, Angelo H (2016) Expand the frontiers of urban sustainability. Nature 536(7617):391–393. https://doi.org/10.1038/536391a
Walker G, Day R (2012) Fuel poverty as injustice: Integrating distribution, recognition and procedure in the struggle for affordable warmth. Energy Policy, 49. https://doi.org/10.1016/j.enpol.2012.01.044
Wooldridge JM (2015) Introductory econometrics: {A} modern approach. Nelson Education
World Commission on Environment and Development (1987) Our common future: report of the World Commission on Environment and Development. Oxford University Press, Oxford, UK
Young DS (2018) Handbook of regression methods. In: Handbook of regression methods. Routledge and CRC Press

Acknowledgements

The views expressed here are purely those of the authors and may not, under any circumstances, be regarded as an official position of the European Commission. The authors warmly than Pietro Florio (Joint Research Centre, European Commission) for extracting georeferenced GDP data used to characterise the cities.

Author contributions

NDV: conceptualisation, formal analysis, visualisation, writing—original draft preparation, writing—review editing. GU: conceptualization, data collection, visualisation, writing—review editing. NV: writing—review editing.

Competing interests

The authors declare no competing interests.

Ethics declarations

Local and regional research relevant to the field of study has been taken into account in the references.

Ethics approval

This article does not contain any studies with human participants performed by any of the authors.

Informed consent

This article does not contain any studies with human participants performed by any of the authors.

Additional information

Supplementary information The online version contains supplementary material available at https://doi.org/10.1057/s41599-023-01953-y.

Correspondence and requests for materials should be addressed to Nives Della Valle.

Reprints and permission information is available at http://www.nature.com/reprints

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit http://creativecommons.org/licenses/by/4.0/.

© The Author(s) 2023