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Investigating the origins of differentiated vulnerabilities to climate change through the lenses of the Capability Approach

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Abstract
The paper traces the evolution the concept of socioeconomic vulnerability to climate change has followed in the academic and scientific debate and examines its effects on wellbeing. The recent recognition of vulnerability as a social construction has shifted the focus of the analysis to the dimension of adaptive capacity, restoring a political economy significance to the study of vulnerability. The social origin of vulnerability is related to the presence of structural inequalities, rooted in structural economic and political relationships and reinforced by historical cultural values and praxes. Structural inequalities and power relations in place within a society shape access to resources and capabilities that can enable individuals or population groups to prevent and cope with impacts from extreme weather events, ultimately defining vulnerabilities. Widespread vulnerabilities to climate change can compromise wellbeing in several ways, including an increase in food insecurity, health issues, outbreak of armed conflicts and mass migrations. In addition, the same individual or population group can be vulnerable in more than one wellbeing dimension and, once a dimension is affected, their own vulnerability to other threats is likely to increase.

Keywords Climate change · Vulnerability · Structural inequalities · Inequality · Capability Approach

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1 Introduction

As discussed during the First Conference of Parties (COP-1) of the UNFCCC, held in Berlin in 1995, while developed countries have historically been the major contributors to climate change impacts through their industrialization process, developing countries are the most affected, without even benefitting from economic growth. According to the Global Climate Risk Index (CRI) 2021, developed by the Germanwatch, 475,000 people died across world countries as a direct consequence of more than 11,000 climate-change related extreme events between 2000 and 2019 (Eckstein et al., 2021). The same report shows that global distribution of climate-change related risks and vulnerabilities is largely unfair. Eight out of ten countries most affected by extreme events between 2000 and 2019 are categorized as low- or lower-middle income countries (Eckstein et al., 2021). Many small island states have lost their homes and livelihoods and, in the worst cases, their entire nations, despite contributing less than 1% to global GHG emissions (UNDP, 2017). These same little states are also the ones projected to suffer the heaviest impacts from climate change if global temperatures exceed the limit of 1.5 °C (King & Harrington, 2018).

The same unfair distribution of climate change impacts is reflected among income and social groups within countries, with poorer and marginalized social groups suffering most of the impacts (Birkmann, 2007; Hsiang et al., 2017). Grounding on extensive evidence of within-country inequalities in climate change impacts (e.g., Roberts and Parks, 2007; Yamamura, 2015; Hallegatte and Rozenberg, 2017; Diffenbaugh and Burke, 2019), the present paper reviews existing literature to investigate the origins of differentiated vulnerabilities to climate change through the lenses of the Capability Approach (Sen, 1981, 1987, 1990). In terms of political economy, structural inequalities are argued to be the drivers of such differences in socioeconomic vulnerability across individuals and population groups. Inequality in the distribution of relevant resources is primarily a question of access to tangible assets, as well as to intangible assets and capabilities that can enable an individual or a population group to prevent and cope with impacts from extreme weather events. In this context, a relevant role is also the one played by institutions and policies, which can either remove obstacles towards a fair distribution of resources or intensify pre-existing inequalities and vulnerabilities. The work is structured as follows: Sect. 2 reviews the definitions of socioeconomic vulnerability to climate change proposed in the literature and the related approaches. Section 3 addresses the roles of access and governance in shaping vulnerabilities. Section 4 investigates how structural inequalities act as drivers of vulnerability, taking into account both vertical and horizontal inequalities. Section 5 outlines the several threats to wellbeing dimensions posed by increased vulnerabilities. Section 6 concludes by discussing possible actions to be undertaken to address vulnerability and inequality.

2 The evolution of the concept of socioeconomic vulnerability to climate change

There have been numerous attempts to provide a reasonable measurement of socioeconomic vulnerability, accounting for the multidimensionality of the concept and comparability across different locations and over time. A certain degree of uncertainty is due to the extensive use of the concept by different disciplines, all with slightly different acceptations (Newell et al., 2005; Füssel, 2012). In addition, the dynamic nature of social vulnerability requires a definition of the concept adaptable to changing institutional contexts (Adger & Kelly, 1999) and environmental and socioeconomic conditions (Cutter & Finch, 2008). Some definitions measure vulnerability to natural and environmental stressors or exposure to natural hazards at the national level (e.g., Dilley et al., 2005; Birkmann, 2007; Edmonds et al., 2020; Eckstein et al., 2021). Other studies propose alternative measures of vulnerability strictly dependent on the local background (e.g., Cutter and Finch, 2008) or hazard-specific (e.g., Cannon, 2006; Cardona et al., 2012). Cannon (2006) and Cardona et al. (2012) identify some global trends, including population growth, skewed urbanization, international financial pressures, increasing socioeconomic inequalities, incorrect governance behaviours and environmental degradation, as important drivers of socioeconomic vulnerability.

What pools these definitions is the centrality of the interaction between human systems and the environment. Importantly, the concept has evolved from considering a passive (e.g., Tegat et al., 1990; McCarthy et al., 2001) to an active (e.g., Cutter and Finch, 2008; Füssel, 2012) role of human systems. Until the first years of 2000s, vulnerability of human systems was only conceived in relation to the physical damages suffered from climate change according to the degree of exposure to adverse events. Hence, differences in the impacts suffered across individuals and population groups were simply explained by the diverse geographical and climatic characteristics of the localities affected. Then, it was observed that in the face of a comparable level of physical impacts, some people suffered harsher harm than others, determining differentiated vulnerabilities across population groups. Accordingly, the focus has shifted to the ability of human systems to respond to stresses, which can either mitigate or heighten their harm, depending on social and institutional factors. It follows that vulnerability is now conceived primarily as a social construction (Wisner et al., 2004; Thomas et al., 2018) and, as such, is a matter of political economy (Barnett, 2020) [1].

Following the same line of evolution, the approach of the Intergovernmental Panel on Climate Change (IPCC) has passed from *climate change adaptation* to *disaster risk management*. In the former (until the report of 2007), vulnerability was understood as a function of exposure, sensitivity and adaptive capacity. It was defined as "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability

[1] For the sake of completeness, it is worth saying that initiators of vulnerability research already conceived vulnerability as tightly coupled with power relations, social structures and persistent poverty and inequality levels (Bohle et al., 1994). However, this tradition struggled to be acknowledged in mainstream vulnerability research and was only recovered in recent years.

is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" [IPCC, 2007 p. 883]. Despite this definition already constituted an advancement compared to the ones provided in previous reports, the focus was still on the exposure to climate change impacts. Then, from the 2014 report on, vulnerability has been understood as a social process, depending only on sensitivity and adaptive capacity. In this framework, the dimension of exposure, although necessary to determine climate impacts, only accounts for the geographical aspects but does not contribute to the creation of vulnerabilities, which have now a purely social and human connotation. With this change of perspective, the process of adaptation to climate impacts has changed accordingly: the adoption of the disaster risk management approach has allowed a shift in the focus from disaster recovery to disaster prevention (Cardona et al., 2012). This can only be possible through a deep understanding of the interactions existing between human systems and the environment, as well as of social, political and economic factors that determine the distribution of key resources and shape vulnerabilities accordingly. In the remainder of the paper, we will draw on the definition proposed by the IPCC in the Fifth Assessment Report of 2014, which defines socio-economic vulnerability as "the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to adapt. A broad set of factors such as wealth, social status, and gender determine vulnerability and exposure to climate-related risks" [IPCC, 2014; p. 1048].

The definition of exposure has changed together with the approach adopted by the IPCC. Until 2007, it was defined as "the nature and degree to which a system is exposed to significant climatic variations". In the report of 2014, the element of exposure loses its role as driver for vulnerability and assumes a spatial connotation (Jurgilevich et al., 2017) and is defined as "the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected." Therefore, if a hazard occurs in an unpopulated area with no valuable resources, technically no disaster can exist. For a disaster to exist, a human system needs to be both exposed and vulnerable (Cardona et al., 2012).

The two intrinsic dimensions of vulnerability, as in the report of 2014, are sensitivity and adaptive capacity. In this case, their definitions have remained substantially unchanged between the reports of 2007 and 2014. Sensitivity is "the degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise)" [IPCC, 2014]. High sensitivity of a human system is the result of context-specific and intrinsic conditions of the system itself. In other words, sensitivity accounts for the weaknesses that make the system predisposed to suffer damages from the occurrence of a hazard. However, such a damage may be prevented or at least mitigated if the system is endowed with adaptive capacity.

Accordingly, adaptive capacity is defined as "the ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences" [IPCC, 2014]. It is a critical property of the system that consists of a set of system-specific attributes (e.g., in agricultural systems, the availability of irrigation systems, or the alternance of crops to facilitate terrain regeneration) that enable the system to reduce and respond to the adverse impacts caused by the incidence of a hazard. On the contrary, vulnerability increases either in systems characterized by a lack of adaptive capacity or in consequence of 'maladaptation' - i.e., the adoption of actions oriented at reducing impacts from climate change, but which instead "increase the vulnerability of other systems, sectors or social groups" (Barnett & O'Neill, 2010). For example, the construction of large dams aimed at improving water security and increasing the share of energy produced by renewable resources may have as a side effect the dislocation of local populations to more exposed locations, as well as an increase in methane emissions (Kallis, 2008). Further, while effectively preventing the risk of smaller floods, large dams often tend to increase the risk of larger floods if not specifically designed for this kind of eventuality or if inadequately maintained. Hence, floodplains that first were uninhabitable become now home to populations whose vulnerability to large floods is increased, with the result of "risk transference" into the future (Fordham, 1999).

Adaptive capacity is a key element in determining an individual's or community's vulnerability in both hazard prevention and recovery. However, the capacity needs to anticipate (ex-ante) disaster risk differ from those to recover from (ex-post) disaster impacts (Cooper et al., 2008). To foster this kind of capacity both structural and policy interventions are needed. Structural interventions include the construction of hazard-resilient buildings as well as hazard-preventing infrastructure. Policy interventions include both land and environmental policy prescriptions (e.g. the prohibition to build in unsafe areas) and others that are strictly related to aspects of political economy aimed at securing livelihoods (Eriksen & Silva, 2009), guaranteeing access to and a fair distribution of relevant resources. The capacity to respond to climate impacts is useful both in the aftermath of an extreme event and as a first anticipatory measure in the face of future events. In the wake of an extreme event, governments should be able to guarantee adequate care and assistance to affected people as well as a fast and effective reconstruction of the buildings and infrastructure hit. Both ex-ante and ex-post adaptive capacity require a long-term perspective as well as the evaluation of costs and benefits of the interventions to recover from current damages and minimize future climate impacts for all population groups. As argued by Sovacool et al. (2018, p. 243), "sometimes, the human response to a natural disaster can exacerbate its impact, even more than the event itself".

While human societies can be vulnerable to specific climate hazards and not to others (hazard-specific vulnerability), some factors heighten vulnerability independently on the type of hazard (Cardona et al., 2012). These factors, including poverty and inequality, have a socio-political nature and are what transforms a hazard into a disaster (Gaillard et al., 2014; Thomas et al., 2018), ultimately threatening wellbeing. Socioeconomic and political factors are the main focus of an emerging strand of research aimed at showing how climate-induced disasters are in fact "unnatural" and the entity of their damages as well as the timing and modalities of recovery mainly depend on the political economy of the country or region where the hazard has occurred (e.g., Weber and Messias, 2012; Cretney, 2017; Sovacool, 2017; Sovacool et al., 2018). The most cited example is Hurricane Katrina, which hit the coast of Lousiana in 2005 causing the death of 1,800 people (and many others missing and severely injured). Although other cities of Louisiana have been affected more severely, most of the victims were concentrated in the city of New Orleans, because of a failure in the levee system meant to protect the city. In consequence of this episode, Hurricane Katrina was defined as “the worst civil engineering disaster” in the history of the USA (Seed, 2007).

3 Access and governance

According to Bohle et al. (1994) social vulnerability to climate change is defined by the interaction of three place- and time-specific attributes: (i) resource endowments (and their quality); (ii) class relations and empowerment, which shape the allocation of the entitlements (*à la* Sen[2]) and secure their ownership; (iii) political ecology, which depends upon the prevailing theory of political economy and governs the methods of production and the distribution of surplus across population groups and social classes. In addition to this, several socioeconomic factors define vulnerable populations, including ethnic group, socioeconomic status, age and gender.

The inspiring work by Amartya Sen on famines has many common points with socioeconomic vulnerability to climate change and, in particular, with the dimension of adaptive capacity. In both cases, access to relevant resources is not guaranteed by their availability, but rather depends on the distribution of entitlements and the role of institutions in defining their allocation. Adger and Kelly (1999) extend Sen’s (1990) analysis of food insecurity to provide an assessment of climate vulnerability that grounds on the “architecture of entitlements”. The authors maintain that the human use of resources, which in its material and social aspects is regulated by the entitlements of individuals and groups, is key in understanding differences in vulnerability to climate change impacts. Also, Schröter et al. (2005) adopt the example of famines to describe the social dimension shaping vulnerability to climate change. They suggest focusing on the marginalization of individuals as induced by social, political and institutional factors as the main cause of vulnerability, rather than on the physical impacts the individuals are subject to. In particular, norms and cultural values, human behaviours and governance structures that characterize a society impose socioeconomic and political constraints and shape the allocation of resources in a way that creates vulnerabilities.

Relevant resources in the face of climate change include both private – e.g., private capital, insurance, owned assets - and public goods – e.g., disaster warning systems, emergency response systems, infrastructure, information and communication technology, etc. (Thomas et al., 2018; Cinner et al., 2018). The lack of access to these resources is what jeopardizes a system’s adaptive capacity to prevent and recover from climate hazards. Vulnerability has both a subjective (endogenous) and a contextual (exogenous) dimension (Lewis, 1999; Wisner et al., 2004; Bankoff et al., 2004; Hore et al., 2018). The exogenous dimension comprehends all socioeconomic, politi-

[2] Cfr. Sen (1981; 1987; 1990).

cal and institutional factors determining access to relevant resources for individuals and groups. The endogenous dimension is related to the inability of people and communities to secure their access to resources, as a result of unawareness and lack of livelihood choices (Gaillard, 2010; Hore et al., 2018). However, this endogenous dimension is largely influenced by exogenous factors as well (Hore et al., 2018).

The primary origin of differentiated access to resources among individuals and groups are the power relations in place in a society. According to these relations some individuals and groups are included within political decisions, while others are left out, marginalized. Several ways in which marginalization takes place exist: according to Gaillard (2010, p.222) "disaster-affected people are marginalised geographically because they live in hazardous places (e.g. informal settlers); socially because they are members of minority groups (e.g. ethnic or caste minorities, disabled individuals, prisoners and refugees); economically because they are poor (e.g. homeless and jobless); and politically because their voice is disregarded (e.g. women, non-heterosexuals, children, and elderly) by those with political power." Adger and Kelly (1999) distinguish between the factors determining individual and collective vulnerability. They maintain that while the former depends on the individual's social status within the community of reference, access to resources and the possibility of diversification of income sources, the latter is related to wider characteristics of society, including institutional and market structures, infrastructure and income, which are all worsened by climate change.

Despite the theoretical paradigm shift that has allowed to consider climate-related risks and disasters as social constructions, as opposed to natural phenomena, policy prescriptions aimed at minimizing and coping with such risks have not followed the same direction, yet (Hore et al., 2018). Albeit there are several examples of local institutions that managed to handle scarce relevant resources, emphasis is still placed on technological and engineering solutions aimed at preventing the physical impacts of a specific array of extreme climate events, often forgetting about the vulnerability of local populations (Gaillard, 2010). Of course, technological solutions are pivotal to prevent climate hazards but, in accordance with the recognition of the social essence of vulnerability, should be implemented in tandem with social and political solutions (Kelman et al., 2015; Sovacool, 2018) contends that socioeconomic vulnerability should be evaluated at the local level, where four mechanisms inducing increased vulnerabilities can take place, namely enclosure, exclusion, encroachment and entrenchment. By enclosure, Sovacool (2018, p. 186) refers to "when an adaptation project transfers a public or social asset into private hands, or expands the role and authority of a private actor into a formerly public sphere". Exclusion occurs "when an adaptation project excludes or displaces a particular group of stakeholders or limits access to resources related to due process, fairness, and procedural justice" (ibid.). Encroachment takes place "when adaptation projects degrade the environment, interfere with ecosystem services provision, intrude upon biodiversity conservation zones such as protected areas and national parks, or counteract climate change mitigation efforts by involving the emission (embodied, or direct) of greenhouse gases" (ibid.). Finally, entrenchment is "when an adaptation project aggravates vulnerability or the disempowerment of women, the chronically poor, and/or other minority groups" (ibid.).

For instance, D'Alisa and Kallis (2016) report the example of maladaptation that had place in Sarno (Italy), after the occurrence of the landslide that affected the area in 1988. According to the authors, maladaptation was the result of the choice to implement harder engineering interventions (i.e., large-scale structural engineering interventions, like dams, canals, etc.) over softer interventions (i.e., structural ecological interventions aimed at restabilising natural functions of the physical environment as well as non-structural interventions at the institutional level). Harder interventions are usually preferred by public institutions over softer interventions because of the huge amounts of capital they help circulate but, especially if implemented alone, are rarely more effective and are often source of increased vulnerability of the areas concerned (D'Alisa & Kallis, 2016). Further, hard interventions not accompanied by soft interventions can often have the undesired effect of risk transference to other vulnerable groups (Hore et al., 2018).

At the international level, this trend reflects the idea of widely applicable development policies whereby rich and safe countries are opposed to poor and endangered countries (Gaillard, 2010). The result is a transfer of knowledge and technologies from developed to developing countries, that once again does not account for local-specific differentiated vulnerabilities. Conversely, when assessing vulnerability of individuals or population groups the local socio-economic and political context where adaptation takes place is of extreme importance. Several studies have documented the local power implications of adaptation plans in different countries. For instance, in Kenya some adaptation programs have altered power relationships so as to reinforce the relative power of some pastoralist communities who, thanks to their gained powerful status, managed to exclude other pastoralist groups from the access to the main water basin of the region (Eriksen & Lind, 2009). Analogously, other adaptation projects in Ghana resulted in a disproportionate workload between men and women, with women more heavily burdened (Carr, 2008; Sovacool, 2018) investigates the consequences of the implementation of the National Adaptation Program of Action in Bangladesh and finds that the processes of enclosure, exclusion, encroachment and entrenchment have hindered an equitable adaptation, favouring some local elites to the detriment of other population groups.

4 Structural inequalities as drivers of socioeconomic vulnerability

Unequal access to key resources and, accordingly, the extent to which individuals and social groups are vulnerable to climate change impacts, is reflected through 'structural inequalities', rooted in structural economic and political relationships and reinforced by historical cultural values and praxes. Structural inequalities operate at the intersection of gender, age, ethnicity, race, religion, social status and can produce unequal access to basic services, unequal relations in role and unequal opportunities for participation and choice (Wilkinson & Pickett, 2010). The presence of structural inequalities may intensify exposure and vulnerability of specific individuals and groups by inducing both an increase in the sensitivity to climate hazards and a lack of adaptive capacity to prevent and recover from the occurrence of extreme events. In general, differentiated vulnerabilities can be seen when, for the same level of exposure, some individuals or groups are more vulnerable than others (Birkmann, 2007). Higher sensitivity is often induced by the limited ability of poor people to choose where to live, being forced to opt for cheaper but often less resistant buildings (Hallegatte, 2012), as well as localities exposed to hazards (Yamamura, 2015). Structural inequalities also undermine adaptive capacity by limiting the affordability of insurance against extreme events and resources that ensure resilience to a small share of the population. The poorer shares, on the other hand, are forced to rely on short-term traditional adaptation measures to confront climatic shocks, such as income diversification and drought-resistant crops, which however are not effective in the face of repeated shocks (Kallis, 2008). Moreover, financial and technical constraints may extend the time needed for reconstruction in the aftermath of an extreme event, further widening the income inequality gap (Hallegatte & Rozenberg, 2017). This can lead to a vulnerability-disaster trap in which structural inequalities undermine adaptation options that, in the aftermath of a climatic shock, further widen the inequality gap and reduce resilience (Cappelli et al., 2021; Thomas et al., 2018) distinguish among three types of adaptive capacities necessary to reduce vulnerability: economic, institutional and political capacity. By lack of economic capacity, they refer to limitations in access to resources imposed by income or wealth constraint. By lack of institutional capacity they indicate the inability of a given group to gain institutional inclusiveness and consideration in the allocation and provision of relevant public resources. Finally, by lack of political capacity they imply neglected access to key resources as resulting from surplus appropriation by other groups. Despite the lack of either capacity results in the group being poor, policies to be adopted to reduce the group's vulnerability differ depending on the type(s) of capacity lacking (Thomas et al., 2018).

It is worth noting that structural inequalities are not a feature characterizing only developing countries: they can be found across and within regions and cities of the wealthiest countries as well. For instance, Hsiang et al. (2017) develop a probabilistic model of future climate impacts at a spatially disaggregated level for the USA counties under a RCP8.5 scenario. They show that impacts from climate change are projected to be extremely differentiated across counties, with the South-Eastern ones especially affected. What emerges is that the distribution of projected damages reflects the current distribution of income across USA counties, with richer counties benefitting and poorer counties suffering from climate change. Indeed, while median losses are expected to exceed 20% of GDP in some counties, in other counties, mainly located in the North-West, median gains are expected to exceed 10% of GDP (Hsiang et al., 2017).

The acknowledgement of structural inequalities is at the basis of the concept of "environmental justice", which was born in the United States of America during the contestations of the "Warren episode". In 1982, the USA government was to decide where to dispose of the highly toxic wastes illegally dumped across 14 counties in North Carolina (Banzhaf et al., 2019). The ultimate choice fell on the Warren County, where 60% of the population was African-American and 25% of families were below the poverty line. The wave of protests in consequence of this decision gave birth to the environmental justice movement and to the acknowledgement of the issues related to environmental injustices by governmental and academic institutions. The

US Environmental Protection Agency (EPA) defines environmental justice as “the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation and enforcement of environmental laws, regulations and policies”. Nonetheless, despite the institutional acknowledgement and the visibility within the public debate, as well as the institution of the “Environmental Equity Workgroup” by the EPA, the USA are still far from achieving environmental justice (Laurent, 2011). Analogously to the Warren episode, several studies (for example, Pfeffer, 2002; McKenzie et al., 2016; Ash and Boyce, 2018) have shown how landfills and other pollution sources have been regularly located in areas characterized by ethnic diversity or social and economic deprivation. Following the diffusion of the concept of environmental justice, the notions of “climate justice” and “just transition” have gotten a foothold among researchers and environmentalist movements, with the specific aim of wondering about the uneven distribution of risks and responsibilities across countries and population groups (Barrett, 2013).

While most discussions about inequality usually focus on vertical inequalities (i.e., income or wealth inequalities between individuals, typically measured by the Lorenz curve and the Gini index), horizontal inequalities (i.e., inequalities among groups) tend to be disregarded. The acknowledgement of horizontal inequalities as well as their relations with vertical inequalities is especially relevant to understand socioeconomic vulnerability to climate change and issues related to environmental and climate justice. While horizontal inequalities constitute a part of vertical inequalities, which are composed of between and within group inequalities, it is sometimes very difficult to achieve targets such as poverty abatement or vulnerability reduction without explicitly addressing horizontal inequalities and the resulting marginalization of specific population groups (Stewart et al., 2005).

4.1 Vertical inequalities

The concentration of income and wealth in fewer hands constraints coping capacity and limits the possible strategies to recover from environmental stresses (Adger & Kelly, 1999). Poorer households often rely on public coping strategies only, but external aid or the transfer of financial resources that do not explicitly account for climate justice, are not always effective in reducing vulnerabilities of low-income households (Scandrett, 2016).

Wilkinson and Pickett (2010) start from the premise that the long-term trend of rich societies of valuing economic growth above income equality, has produced manifold negative outcomes in terms of wellbeing. The authors show, by means of a series of scatterplots that relate income inequality with several health, social and environmental indicators, that the unequal distribution of income strongly affects the quality of life even in richer nations. As they argue, “it often looks as if the effect of higher incomes and living standards is to lift people out of these problems. However, when we make comparisons between different societies, we find that these social problems have little or no relation to levels of average incomes in a society” [Wilkinson and Pickett, 2010; p. 11]. They take health as an example, considering only rich countries: while a country can be twice as rich as another, it does not translate in any improvement in terms of life expectancy. Then, focusing on the USA only, they show that death rates are systematically associated with the level of income, with people in the lowest tails of the distribution being always more affected.

Wilkinson and Pickett (2010) contend that income inequality is representative of the degree of a society's "social stratification". In countries characterized by a high social stratification, there are usually also higher fragmentation, hierarchy, and minimal interactions between different social groups. According to the authors, material inequalities lay the foundations for the formation of class and cultural differences: mere differences in income and wealth evolve over time in differences in attributes shaping class identity, including differences in clothing, consumption, education possibilities, etc. Social stratification and the differentiated possibilities in consumption it entails is what also determines vulnerability, as resulting from differences in the affordability of mechanisms preventing from and coping with climate-change induced hazards. Explicitly addressing differentiated vulnerabilities when designing preventing and recovery strategies from extreme events is essential to avoid widening the inequality gap and exacerbating pre-existing vulnerabilities. For instance, in the aftermath of Hurricane Harvey, which hit Houston in 2017, 20% more credit-constrained homeowners experienced bankruptcies compared to homeowners covered by flood insurance (Billings et al., 2022). Another example is the severe earthquake that struck Canterbury, New Zealand, in 2010. In that occasion, a fifth of the population affected was not covered by insurance and the recovery process was entrusted to market mechanisms that did not account for vulnerabilities and income differentials (Sovacool et al., 2018). As a result, most resources were devoted to the reconstruction of the economic activities located in the city centre, leaving poorer households behind and further widening the inequality gap (Sovacool et al., 2018).

4.2 Horizontal inequalities

Categorisation in groups can take place based on different aspects (e.g., ethnic group, gender, age, class, caste, etc.) and can be the result of self-identification, identification by others or a combination of both (Stewart et al., 2005; Stewart, 2009). Being part of a group can sometimes influence positively or negatively the wellbeing of individuals belonging to it, especially when: (i) individual's mobility across groups is impossible or very difficult; (ii) individuals are treated differently (privileged or discriminated) because belonging to a certain group; (iii) a relevant part of an individual's identity is related to group membership (Stewart et al., 2005). In these cases, the individual's wellbeing does not depend solely on their own social status and access to resources, but also on their group's power relationship compared to other groups. To illustrate, several studies (e.g., Boyce, 1994; Torras and Boyce, 1998; Boyce, 2002) have observed how differences in power distribution widen the gap between those who bear environmental costs and those who gain from environmental benefits, ultimately leading to higher environmental degradation. Further, horizontal inequalities do not refer exclusively to differences in income distribution but in choices and possibilities as well. In the context of adaptation to climate change, these differences can in some cases be even more relevant than mere differences in income, as they can severely constrain adaptation options, determining differentiated vulnerabilities across population groups. Several studies have investigated differentiated vulnerabilities to climate-related hazards, as resulting from ethnicity, socioeconomic status and class, gender, and age.

4.2.1 Ethnic groups

Structural racism, which comprehends "the totality of the social relations and practices that reinforce white privilege" (Bonilla-Silva, 2013, p. 9), is not as evident as open acts of racism were in the past but, analogously, contributes to the preservation of white privileges through creating less visible inequalities in access to resources (Shearer, 2012). This results in disparities in educational attainment, income and wealth (Thomas et al., 2018) that constrain adaptation possibilities to climate change and increase vulnerability of marginalized ethnic groups. Sovacool et al. (2018) analyse some of the major climate-related disasters occurred in the last years to detect the presence of the mechanisms of enclosure, exclusion, encroachment and entrenchment. In particular, marginalization arises in the presence of the mechanism of entrenchment, according to which some ethnic groups may be located in areas where sensitivity and exposure are higher or may be discriminated in the phase of disaster recovery. For instance, the authors show how the mechanism of entrenchment took place when Hurricane Katrina hit the coast of Louisiana, USA. African Americans underwent both disproportionate impacts (Driesen et al., 2005; Elliot and Pais, 2006) and uneven recovery processes (Masozera et al., 2007; Bullard and Wright, 2009) in the aftermath of the hurricane, compared to white people. Analogously, the entrenchment mechanism was found in the disproportionate disbursement of official aid across religious groups in Thailand after the tsunami that hit Malaysia, Thailand, India, East Africa and Sri Lanka in 2004 (Sovacool et al., 2018).

4.2.2 Age groups

Children and the elderly are especially vulnerable to climate-related extreme events. Bartlett (2008) argues that children's incomplete physical development as well as their immature immune system make them more susceptible to vector-borne diseases. Further, both children and the elderly are more vulnerable to heat-related stress because of their reduced thermoregulatory capacity (Grundy, 2006). In particular, elder people are more likely to suffer from respiratory and cardiovascular diseases related to extreme heat and cold temperatures and especially if they live in nursing and residential homes (Hajat et al., 2007). Children and the elderly are also more vulnerable in the aftermath of the event, as they lack capacity to cope with hazards. For instance, when Superstorm Sandy that hit New York and New Jersey in 2012, most deaths involved elder people because of their constrained access to healthcare and transportation (Kunz et al., 2013).

4.2.3 Gender

Contrary to vulnerabilities related to age structures, gender-related vulnerabilities do not depend on biological differences between men and women. In most cases, they are driven by socio-political and institutional factors that cause women and girls to be relegated to working in jobs more exposed to hazards, or to be excluded from decision-making processes and access to relevant resources (Denton, 2002; Sultana, 2014) or, again, to be discriminated during the phase of recovery from a hazard (Houghton, 2009; Sultana, 2010; Sovacool et al., 2018). For instance, in relation to the latter aspect, Sovacool et al. (2018) report of a gender and rural bias in the disbursement of aid in the Philippines, in the aftermath of Typhoon Yolanda in 2013. Further, in some countries gender-related vulnerabilities are also related to religious, cultural and class factors (Ray-Bennett, 2009; Arora-Jonsson, 2011), which may hinder women's possibilities to evacuate and recover from extreme events in the absence of the male head of the family (Sultana, 2014).

4.2.4 Social status

In several countries, discrimination takes the form of hierarchical relations among individuals belonging to different castes. Such castes can be either officially or not officially acknowledged, but in both cases the type of relationship that is established can deeply influence vulnerabilities to climate change impacts (Ray-Bennett, 2009). The unequal social status characterizing castes leads to the establishment of patron-client relationships between people belonging to different castes, often bringing about exploitation processes and dependencies of people of lower castes (Onta & Resurreccion, 2011). Such dependency shapes access to food, water, land, education, disaster warning systems and recovery mechanisms (Mustafa et al., 2010; Ray-Bennett, 2009) and, in countries like Nepal, it often determines political exclusion of people in lower castes (Nagoda & Nightingale, 2017).

5 Vulnerability-driven threats to wellbeing dimensions

High levels of climate change vulnerability can compromise wellbeing in several ways, including an increase of food insecurity, health issues, outbreak of armed conflicts and mass migrations and displacements (Otto et al., 2017). The following paragraphs examine each of these threats to wellbeing. It is worth noting that multiple threats may occur at the same time and place, both independently one from another and as a result of the interaction among different coexisting threats. The same individual or population group can be vulnerable in more than one wellbeing dimension and, once a dimension is affected, their own vulnerability to other threats is likely to increase.

5.1 Food insecurity

As observed in the previous sections in relation to famines, socioeconomic vulnerability to climate change and food insecurity have several aspects in common. According to the Food and Agriculture Organization (1996), food security is composed of four dimensions: "(i) the availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports (including food aid); (ii) access by individuals to adequate resources (entitlements) for acquiring appropriate foods for a nutritious diet; (iii) utilization of food through adequate diet, clean water, sanitation, and health care to reach a state of nutritional well-being where all physiological needs are met; and (iv) stability, because to be food secure, a population, household or individual must have access to adequate food at all times. They should not risk losing access to food in consequence of sudden shocks (e.g., an economic or climatic crisis) or cyclical events (e.g., seasonal food insecurity). The concept of stability can therefore refer to both the availability and access dimensions of food security."

Climate-induced food insecurity can be due to either decreasing crop yields (Das Gupta, 2013) or increasing food prices (Nelson et al., 2009). Several impacts on climate-induced food security are already appreciable from observed data (Lobell et al., 2011) and future projections are anything but reassuring. The Sixth Assessment Report (AR6) of the IPCC confirms, supported by new evidence, conclusions to which previous reports came to on climate change-induced impacts on food security (IPCC, 2022). According to the study, climate change will have differentiated impacts on food security in terms of both latitudes where vulnerable populations and food productions are located and yields of different crop typologies. Low- to mid-latitude and dryland areas are generally found to be the most at risk (Das Gupta, 2013; IPCC, 2022). In these regions, even small increases in local temperatures can be detrimental to crop yields and threaten food security of local populations. Maize yields are found to be affected already with global warming above 1.5 °C in vulnerable populations and socio-ecological systems, with risk of crop failure estimated to increase from 6 to 40% (IPCC, 2022).

Simelton et al. (2012) reach similar conclusions about crops vulnerability and contend that the same crops respond differently to droughts if produced in developed (where investments in agriculture are higher) or developing countries. Moreover, climate change is projected to severely exacerbate both water scarcity and the frequency of floods in the next decades (e.g., Schewe et al., 2014; Gosling and Arnell, 2016), with the risk to comprise, in turn, a fair utilization of and access to food resources (Wheeler and von Braun, 2013). As for the access dimension, an increase in food prices may seriously undermine poorer households' access to food, compromising their food security. In addition, following Engel's law, poorer households tend to spend a higher share of their income on food and essential resources compared to richer households, hence an increase in food prices likely contributes to widening the inequality gap. Among strategies to cope with food insecurity, Otto et al. (2017) report the switch to cheaper and lower-quality staples, the reduction of quantities of food ingested (often by women who sacrifice themselves to leave more food for children and husband), the placement in the job market of other family members.

5.2 Health issues

Chapter 7 of the AR6 by the IPCC is all devoted to the assessment of health effects as resulting from climate change. Some recognized health effects from climate change include vector-borne diseases, water-borne diseases, food-borne illnesses and malnutrition, heat-related morbidity and mortality, injuries from extreme weather events, cardiovascular and lung diseases from air pollution, increased aeroallergens from poor air quality (IPCC, 2022). Other health effects are likely to result from climate change but not openly acknowledged. Heat-related impacts are especially relevant, especially for younger and older people (Grundy, 2006; Hajat et al., 2007). In 2020, heatwaves exposure increased up to 3.1 billion more person-days among people older than 65 and 626 million person-days among children younger than 1 compared to the annual average for the period 1986–2005 (Romanello et al., 2021). Further, heat-related impacts also reflect differentiated vulnerabilities, as disadvantaged households may not afford air-cooling or may be more exposed because of the job in which they are employed (Romanello et al., 2021) or because they are homeless (Walters & Gaillard, 2014). Analogous outcomes in terms of age- and gender-differentiated vulnerabilities are found in the case of floods (Khan et al., 2011).

Human health is also compromised by indirect effects, for instance mediated by climate change-induced food and water insecurity or by air pollution and water-borne diseases (Romanello et al., 2021). Even in the case of climate-related health issues, inequality in access to healthcare systems acts as a driver of differentiated vulnerabilities among individuals and groups. Several studies (e.g., Kallis, 2008; Stanke et al., 2013; Sena et al., 2014; Ebi and Bowen, 2016) have documented the (mainly indirect) health effects of long-term droughts. All studies agree on the fact that low-income countries are the most heavily affected and that health-related impacts of droughts are the result of socioeconomic issues, including poverty, food and water insecurity and displacement. Both direct and indirect health effects, as well as the prevalence of some infectious diseases over others are strictly local-specific, depending on a multitude of interacting socioeconomic, political and environmental factors (IPCC, 2022). Further, future impacts of climate change are projected to aggravate existing illnesses in places where are already widespread, as well as to extend them to other localities and to favour the emergence of new illnesses (IPCC, 2014).

5.3 Conflicts

Armed conflicts are a serious threat to livelihoods and development, so much that Collier (2003) define them as “development in reverse”, because of the costs they impose to societies and the lingering effects they have on the whole economy for several years after the conflict has ended. In the same way as armed conflicts, climate change is a major security concern and affects crucial aspects of human life especially in developing countries, through its impacts on agriculture and food security, access to water and other resources (Cappelli et al., 2022). This may exacerbate the social disorder and instability already present in those countries, likely fuelling conflicts (Weir & Virani, 2011). Indeed, even though socio-economic and institutional circumstances are crucial in explaining the onset and evolution of conflicts (Buhaug, 2010), climate change and resources endowment may reasonably act as “threat multipliers”. Hsiang and Burke (2014) review 50 independent studies examining the impacts of climate change on conflicts and find strong support for a causal link ranging across regions, time intervals and spatial scales, despite the debate about the mechanisms through which it operates is still open. The latest IPCC report states that “at higher global warming levels, impacts of weather and climate extremes, particularly drought, by increasing vulnerability will increasingly affect violent intrastate conflict" (IPCC, 2022). In particular, factors such as marginalization and income inequality may fuel political instability and undermine social cohesion (Lessman, 2016), making a country particularly vulnerable to post-disaster violent activities. Horizontal inequality also matters: on the one hand, differences in the treatment of groups who are believed to face similar economic and social challenges may contribute to undermining socio-political stability, increasing conflict risk (Hillesund et a., 2018). On the other hand, because different groups react differently to environmental stressors, politically excluded ethnic groups, as well as social groups over-reliant on agriculture, are more likely to be victims of violence (von Uexküll et al., 2016). According to Buhaug and von Uexkull (2021), pre-existing vulnerabilities and climatic variations might compound and bring about detrimental effects on several socio-economic outcomes which, in their turn, might further increase vulnerability, triggering a vicious cycle of heightened vulnerability, conflict risk and climatic impacts.

5.4 Migrations

Analogously to armed conflicts, climate change is generally acknowledged to foster international and intra-country migrations, but the relative importance of its contribution compared to other causes is still hotly debated (de Sherbinin et al., 2011a). Several mechanisms owing to climate change may force people to migrate, everything else being equal. Among these are, for instance, food insecurity and the deterioration of land productivity and rural livelihoods in consequence of long-term droughts, or displacement in the aftermath of extreme events like floods, landslide, or wildfires that forces relocation and rebuilding somewhere else (IPCC, 2014). A great source of uncertainty is also related to the quantification of migration flows under future climate change scenarios. Temperature increases ranging between 2° and 4° degrees, as projected by the IPCC, may completely overturn known patterns of displacement, likely requiring different policies than the current ones (Gemenne, 2011). In addition, displacement may also be the result of the implementation of mitigation and adaptation policies, especially in relation to the building of large projects (de Sherbini et al., 2011a).

Migration is now acknowledged by many to be a form of adaptation (McLeman & Smit, 2006; Tacoli, 2009) or as a failure to adapt (de Sherbinin et al., 2011b). However, the many other motives inducing people to migrate and the uncertainty in reconducting some indirect mechanisms fostering climate migration poses problems in the recognition of the status of climate refugees and migrants. People who resort to migration are not usually the poorest and most vulnerable households (Black et al., 2011), who cannot afford it, but those who either do not have access to land or had access to a land that has now become unproductive (Obeng-Odoom, 2017). Several studies investigate empirically climate-induced displacement focusing either on rural-urban (e.g., Mueller and Osgood, 2009; Saldaña-Zorrilla and Sandberg, 2009; Nawrotzki et al., 2017) or international migration (e.g., Feng et al., 2010; Marchiori and Schumacher, 2011; Maurel and Tuccio, 2016). According to Marchiori et al. (2012) rural-urban and international migrations constitute different views of the same phenomenon and suggest looking at the overall picture. Indeed, people initially move from rural areas, made increasingly uninhabitable in consequence of climate hazards and environmental stresses, to urban areas. Then, the increasing pressure exerted by rural migrants on urban areas, favours international migration (Marchiori et al., 2012).

6 Discussion and conclusions

With rapidly changing climate, extreme events are projected to occur with still increasing frequency and intensity in the coming years. This can seriously enhance vulnerability of poorer individuals and population groups, as well as increase the number of people endangered and fallen into poverty. In some situations, the repeated frequency of extreme events may not consent a full recovery and preparedness ahead of the next event, further exacerbating vulnerabilities and locking poorer and marginalised people in a vulnerability-disaster trap (Cappelli et al., 2021). In this framework, strengthening local adaptive capacity, primarily facilitating access to key resources, is a mechanism through which vulnerable individuals and population groups may reinforce their own resilience and be prepared for multiple events to come. To do so, it is important to recognize both climate change as a man-made process and vulnerabilities as a social construction. The result is a complex twist of interrelations between nature and society that, driven by power relations that shape the degree of social and economic inequalities, and further complicated by the additional interweaving among climate-induced impacts on wellbeing dimensions, determines winners and losers. Diverse typologies of vertical and horizontal inequalities interact with one another creating multi-faceted vulnerabilities to the impacts of climate change. For instance, women in the upper castes in India rarely lack access to relevant resources and suffer damages from extreme events. On the contrary, access to resources for women in the lower castes are doubly constrained by their caste belonging and male-female relationships which limit their freedom to act and react (Ray-Bennett, 2009). Further, climate change impacts on one dimension of wellbeing may likely cause other dimensions to be affected. Therefore, the challenge here is how to bring structural inequalities and differentiated vulnerabilities back in the agenda of policymakers.

Recent years have witnessed a proliferation of literature on the need of ‘transformation’ for a successful adaptation to climate change (e.g., Ribot 2011; Pelling et al., 2015; Bahadur and Tanner 2014). In particular, the need for transformation (sometimes also referred to as ‘transformative adaptation’) has emerged as an alternative to incremental adjustments in climate change adaptation - mainly reliant on technological solutions but often overlooking the social causes of vulnerability – that have dominated policy responses of the last decades (Godfrey-Wood et al., 2016). In this vein, demand for transformation can be viewed as a step forward in the definition of policies interpreting vulnerabilities as an outcome of social systems, resulting from the crystallization of structural inequalities, and a matter of political economy. However, it raises the question of which kind of transformation will be necessary to ensure a just ecological transition and generate sustainable and equitable wellbeing for the world’s population. Transformation can indeed encompass a wide variety of changes, ranging from commitments to changing behaviours to technological and social innovations (Bahadur & Tanner, 2014), all fundamental for the ecological transition and to address vulnerabilities, but that do not necessarily imply a structural change. For a structural change to be realized, power and institutional structures that create and perpetrate inequalities and vulnerabilities should be deconstructed. If, on the contrary, the ecological transition is undertaken in non-transformative ways, thus neglecting issues related to climate justice, some may gain from such transition, while others may result increasingly vulnerable. An example is the cobalt and coltan curse that has affected Democratic Republic of Congo (DRC) in the last decades. The country hosts some of the major mines of these two metals, which are essential for the production of mobiles and electric vehicles batteries. If, on the one hand, the exploitation of cobalt and coltan mines has contributed to the diffusion of electric vehicles in richer countries, an undoubtedly cleaner alternative to conventional automobiles, on the other hand, it has led to numerous conflicts to take control of these resources in DRC (Lalji, 2007). Policy responses should therefore be downscaled at the local level, where vulnerability is experienced and should importantly be evaluated systemically, considering the crossroads among different socioeconomic impacts and population groups.

Moreover, new research is needed to link the understanding of vulnerability as a social construction to the study of the other side of climate change - i.e., mitigation. Rising inequality in income and wealth distribution, as well as in carbon footprints, demands for a holistic assessment of adaptation to and mitigation of climate change through the lenses of structural inequalities. In addition, ignoring inequalities and vulnerabilities can have skewed outcomes not only in terms of adaptation, but of climate change mitigation as well. As Wilkinson and Pickett (2010, p. 217) contend, “given what inequality does to a society, and particularly how it heightens competitive consumption, it looks not only as if the two are complementary, but also that governments may be unable to make big enough cuts in carbon emissions without also reducing inequality”. It is therefore unthinkable to solve the climate crisis without addressing inequalities and vulnerabilities because the benefits obtained by acting on only one of these two aspects risks being neutralized by not acting on the other. Barrett (2013) argues that climate change involves “a double inequality”, determined by the opposite distribution of impacts and responsibilities. Empirical research confirms that higher income and wealth inequality are correlated with higher average CO_2 emissions (Jorgenson et al., 2017), with the richest 10% of the world population being responsible for 52% of GHG emitted in the atmosphere between 1990 and 2015 (Gore, 2020). Jorgenson (2015) shows that the Veblen effect on consumption induced by income inequality (Bowles & Park, 2005), according to which households in the lower tails of the distribution emulate consumption of wealthier households, in turn results in increased energy use and emissions. With this in mind, policies to mitigate GHG emissions should account for the differentiated effects they would have on households in the different quantiles of income distribution to avoid regressive effects and increasing vulnerabilities.

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