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National 'fair shares' in reducing greenhouse gas emissions within the principled framework of international environmental law

Lavanya Rajamani^a, Louise Jeffery^b, Niklas Höhne ^{b,c}, Frederic Hans^b, Alyssa Glass^a, Gaurav Ganti ^d and Andreas Geiges^d

^aFaculty of Law, University of Oxford, Oxford, UK; ^bNewClimate Institute, Cologne, Germany; ^cEnvironmental Systems Analysis Group, Wageningen University, Wageningen, The Netherlands; ^dClimate Analytics, Berlin, Germany

ABSTRACT

This article tests fairness justifications offered in 168 nationally determined contributions (NDCs) to the 2015 Paris Agreement against the touchstone of principles of international environmental law. It finds that while many NDCs refer to elements and indicators that are backed by principles of international law in determining fair shares (sustainable development, special circumstances, common but differentiated responsibilities and equity), some NDCs justify their contributions on the basis of indicators not backed by such principles (indicators including small share of global emissions (for states that are not LDCs and SIDSs), least cost pathways, and emissions per GDP). These insights are used to select a sub-set of approaches to the quantification of national fair share emissions targets among approaches previously surveyed in the literature. This leads to the exclusion of approaches based on cost and grandfathering. Next, the principles of harm prevention and precaution, and the normative pillars of the climate change regime, including its objective, 'progression', and 'highest possible ambition,' and the norms relating to human rights, are engaged to argue for further narrowing the range of national fair shares such that the sum of individual contributions is collectively compatible with the Paris Agreement's long-term temperature goal. This leads to the finding that developed states have a Paris temperature goal compatible emission level in 2030 that is net-negative. Of the G20 states, only India and Indonesia can temporarily increase their emissions relative to 2010, only India relative to today. Around half the G20 states have increased emissions over the 2010s, and those decreasing emissions have done so too slowly.

Key policy insights:

- States' fairness justifications for their contributions to the Paris Agreement should be scrutinized for compatibility with widely-accepted principles of international environmental law as well as the normative pillars of the climate change regime.
- Fair share ranges consistent with international environmental law principles offer a benchmark for existing and new nationally determined contributions under the Paris Agreement, for peer-to-peer comparisons, and to feed into the global stocktakes.
- Such fair share ranges can inform climate litigation in which the adequacy of national contributions, and thus a state's fair share, is at issue.


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CONTACT Lavanya Rajamani  lavanya.rajamani@law.ox.ac.uk

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1. Introduction

It is becoming rapidly evident that the international community is not on track to averting catastrophic climate change and that states' national mitigation contributions are fundamentally inadequate to limit global temperature to the 'well below 2°C' and '1.5°C' goal identified in the 2015 Paris Agreement (Höhne et al., 2017, 2020; IPCC, 2018b; Rogelj et al., 2016; UNEP, 2019, 2020; UNFCCC, 2016).

It is axiomatic that national mitigation contributions need to increase, and the architecture and logic of the Paris Agreement is premised on iteratively more ambitious contributions over time. However, states have differing views on the share of their contribution towards closing the emissions gap to meet the global temperature goal (Climate Equity Reference Project, 2018; Höhne, den Elzen and Escalante, 2014; Robiou du Pont et al., 2017). The Paris Agreement does not contain a mechanism to review the adequacy of each state's contribution to the global mitigation effort. In its absence, national and regional courts are being asked to consider if the actions pledged by a state are adequate. A key component in determining the adequacy of an individual state's contribution in the context of a collective action problem is whether that contribution represents a fair share of the global effort.

This was considered in the landmark *Urgenda* case in the Dutch Supreme Court (Supreme Court of the Netherlands, 2019, para. 6.3 and 6.5) as well as in the recent *Neubauer et al* case in the German Federal Constitutional Court (Federal Constitutional Court of Germany, 2021). It has also been raised by claimants in ongoing cases before the European Court of Human Rights – the Portuguese children's case against 33 European states (European Court of Human Rights, 2020a; Liston, 2020), a case brought against Austria by an applicant with a temperature-dependent form of multiple sclerosis (European Court of Human Rights, 2021), and a case brought by a group of senior women against Switzerland (European Court of Human Rights, 2020b). Although the phrase 'fair share' is frequently used, there is no single accepted definition of the term. This article uses the term 'fair share' to mean a share of the effort for mitigating climate change that is in accordance with the equitable principles of international environmental law.

The Paris Agreement deliberately sidesteps the contentious issue of fair shares. However, the rules for presenting nationally determined contributions initially contained in the 2014 Lima decision (UNFCCC, 2014), and later extended and embedded in the 2018 Paris Rulebook require States to regularly review, update and provide narrative justification for the ambition and fairness of their nationally determined contributions (UNFCCC, 2019b, Annex I, para 6). Scholars have examined these narrative justifications and identified the indicators that States have put forward to assess the fairness of their contributions (Winkler et al., 2018). They find that states rarely use the indicators to quantify fair emissions reductions for themselves, let alone for other states.

More broadly, scholars have used such indicators to derive national fair shares in addressing climate change in terms of national emission targets, so that these can be compared with nationally determined targets (Climate Equity Reference Project, 2018; Höhne et al., 2014; Robiou du Pont et al., 2017). This scholarship reflects considerable scientific and political debate on how equity and fairness, however understood, can inform the ambition of national mitigation contributions (emission targets). Diverse perspectives on fairness have resulted in a wide range of self-serving calculations and justifications of national fair shares. However, not all of these equity and fairness perspectives, and thus not all the indicators that states have identified in their justifications, accord with widely accepted principles of international environmental law, many of which states refer to explicitly or implicitly even *in* their nationally determined contributions.

This article seeks to determine if the indicators that states and scholars rely on in assessing national fair shares withstand a test against the touchstone of the principles of international environmental law. If not, we analyse how the range of fair share calculations would change if the impugned indicators were excluded in the calculation of what constitutes a fair national greenhouse gas emission target for each state. In anchoring the discussion of national fair shares in the principled framework of international environmental law, this article seeks to address a gap in the literature that has thus far modelled national fair shares, without reference to the equitable principles of international environmental law. In doing so, this article seeks to distil principled limits, albeit within an interpretative range, to the narrative justification as well as the quantified fair shares that states contribute to the global effort.

Equity and fairness can be assessed in qualitative as well as in quantitative terms. Both approaches have their merits, and this article engages with the narrative as well as its translation into quantified outcomes, while acknowledging that not all qualitative assessments of equity can be translated into quantitative outcomes. This article offers an illustrative template for how such translation might occur within these limits.

This article is structured as follows. Section 2 identifies the principles of international environmental law that are engaged in relation to national fair shares. Although the list of principles is not exhaustive, it is representative in that it includes all key, widely referenced (including in the NDCs) principles. Section 2 examines, in particular, the extent to which states' nationally determined contributions refer, explicitly or implicitly to principles of international environmental law. It explores the legal status, core content and operational relevance of particular principles of international environmental law, as well as the normative pillars of the Paris Agreement in determining, interpreting and implementing national fair shares. Section 3 demonstrates the impact of applying international environmental law principles on the quantification of fair share emission ranges for individual states by identifying, collating and curating the relevant literature.

2. Principles of international environmental law & nationally determined contributions

2.1. Nature, spread and legal status of principles of international environmental law

International environmental law comprises a discrete set of customary international law obligations, a dense network of multilateral environmental treaties, and an ever-expanding universe of soft law norms. Although soft law norms are by definition not binding on states, their relevance and reach in international environmental law far exceeds their formal legal character. Principles of international environmental law form the bedrock of this field and are spread across these different sources of international environmental law. Principles of law are ones 'which officials must take into account if it is relevant as a consideration' (Dworkin, 1977, pp. 24–27). They are norms to be taken into account in evaluating conduct rather than norms of conduct themselves (Bodansky, 2004, p. 277). Some scholars make a distinction between concepts and principles – only categorizing as principles those norms that perform 'decision-making' functions (Viñuales, 2020). This article takes a broader approach by including in its categorization of principles norms that play an interpretative function and exert a strong 'directional pull' on state behaviour both in terms of what states *do* and *say*.

The principles of international environmental law, many first articulated in the 1992 Rio Declaration include principles relating to harm prevention, precaution, sustainable development, special circumstances, equity (inter- and intra-generational), common but differentiated responsibilities, public participation, international cooperation and good faith (ILA, 2014; United Nations, 1992a, principles 14, 15, 1, 6, 7, 10, 19, 27). Some of these principles are general principles of international law such as the principle of harm prevention, precaution, international cooperation and good faith. Others are general principles of international environmental law, for instance the principles relating to special circumstances, common but differentiated responsibilities, and sustainable development (although these have occasionally been applied in areas beyond international environmental law). Some of these principles have found expression in treaty obligations, as for instance principles relating to public participation (UNECE, 1998). Yet others are principles of international environmental law that have acquired distinctive content and character in the climate change regime, as for instance the principle of 'common but differentiated responsibilities' – with the addition of 'respective capabilities' in its articulation in the FCCC, and the clause 'in light of different national circumstances' in the 2015 Paris Agreement (UNFCCC, 2015, Article 2.2; United Nations, 1992b, Article 3.1).

The core content of each of these principles varies, and lends itself to an interpretational range, which fosters dynamism, flexibility and evolution of the principle. The formal legal status and operational significance of each principle also differs. While space limitations preclude an extensive discussion of the legal status of each of these principles, it is worth noting at the outset that even though some of these principles have limited *formal* legal status (i.e. they are not binding), they are nevertheless recognized as salient in the international environmental regime. Scholars characterize them variously as 'framework' principles (Birnie et al., 2009), 'constitutional' principles (Aguila & Viñuales, 2019, p. 3), or 'orienting' principles (Martin, 2018, p. 14). However these principles are defined and characterized, they form a fundamental part of the 'conceptual architecture' of

international environmental law, and create a strong directional pull by playing a decisive role in the interpretation of obligations in this field (Rajamani, 2006, 2018a). These principles work collectively and in tandem with each other. While the emphasis in each principle may be different, these principles, as with other rules of international law, are interpreted harmoniously, and so as to give effect to them all. Taken together these principles are the connective tissue that holds the international environmental regime together, and occupies many of the normative gaps in the field.

2.2. Principles of international environmental law in nationally determined contributions

Many of these principles find reference, either explicit or implicit, in the nationally determined contributions (NDCs) of states under the 2015 Paris Agreement (UNFCCC, 2015, Article 4.2). To be clear, the engagement and application of these principles does not hinge on their invocation by states in their NDCs under the 2015 Paris Agreement. However, invocation of these principles by states has legal and political consequences. First, such invocation reflects state practice and, in some cases, *opinio juris* (the belief that the conduct is obligatory) in relation to the invoked principle. This strengthens the principle's normative core as well as contributes to its crystallization as custom in international environmental law. Second, such invocation demonstrates the operational and narrative salience of the principle in the exercise of state discretion in arriving at, framing and justifying national contributions. In other words, it demonstrates the strong 'directional pull' of the principle. Third, and more broadly, it underscores the principled basis of the climate change regime. The principled basis of the regime is often obfuscated in the depiction of the 2015 Paris Agreement as a pragmatic compromise between competing political interests. Indeed, many welcomed the Paris Agreement because it paved the way for international cooperation by side-stepping 'distributional conflicts' (for example, Falkner, 2016). Finally, widespread references to principles in the NDCs – principles that demand thoughtful consideration of distributional impacts – reinforces the need to assess and account for equity and fairness in the international discourse and implementation of national fair shares. (Figure 1).

This article reviews the NDCs submitted till 31 December 2020 (the first round submitted around 2015 and where applicable, the second round of revised and new NDCs submitted around 2020) (see Figures 2 and 3) with a view to tabulating references to:

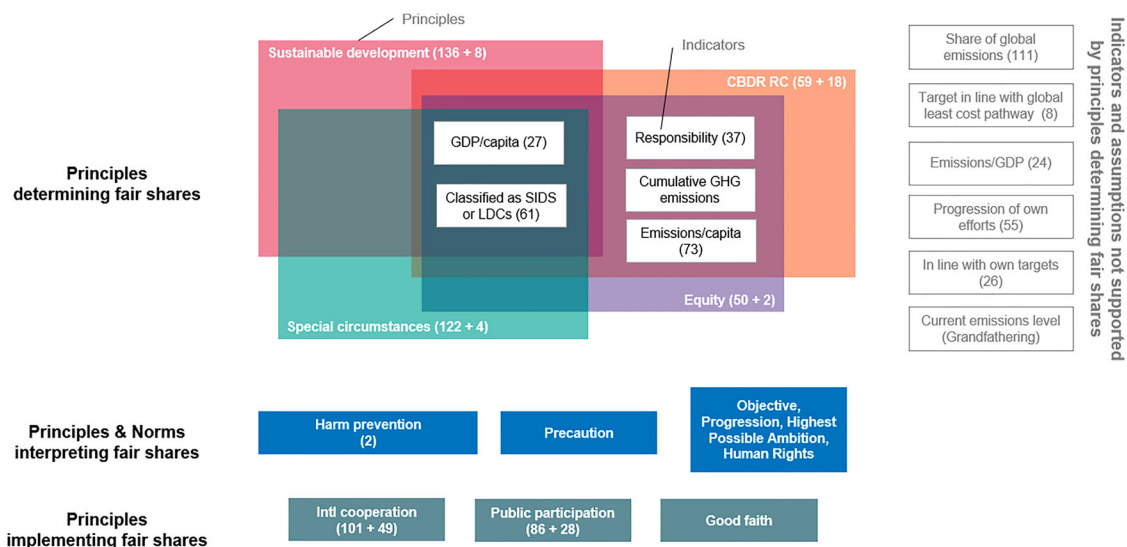


Figure 1. Mapping of principles and norms of international environmental law (coloured boxes) and indicators (white boxes). Numbers in brackets indicate the number of NDCs in which a principle or indicator is mentioned. Where two numbers are given, the first is an explicit reference and the second, implicit.

Principles of international environmental law explicitly and implicitly referenced in NDCs

(total of 168 NDCs as of 31 December 2020)

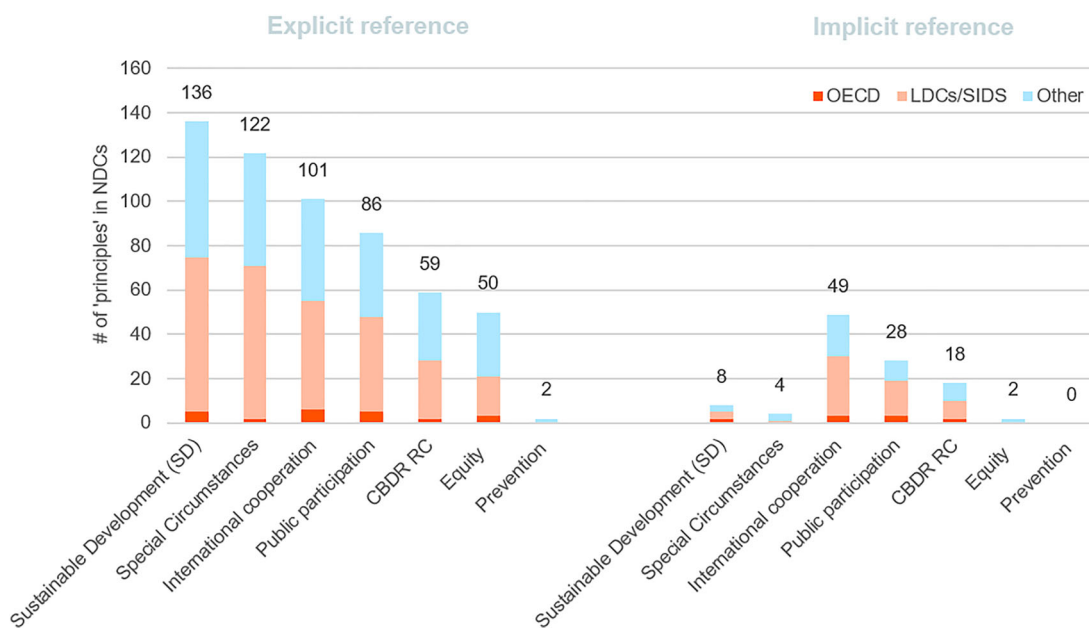


Figure 2. Implicit and explicit references to principles of international environmental law in 168 NDCs submitted as of 31 December 2020.

Indicators of equity referenced in NDCs

(total of 168 NDCs as of 31 December 2020)

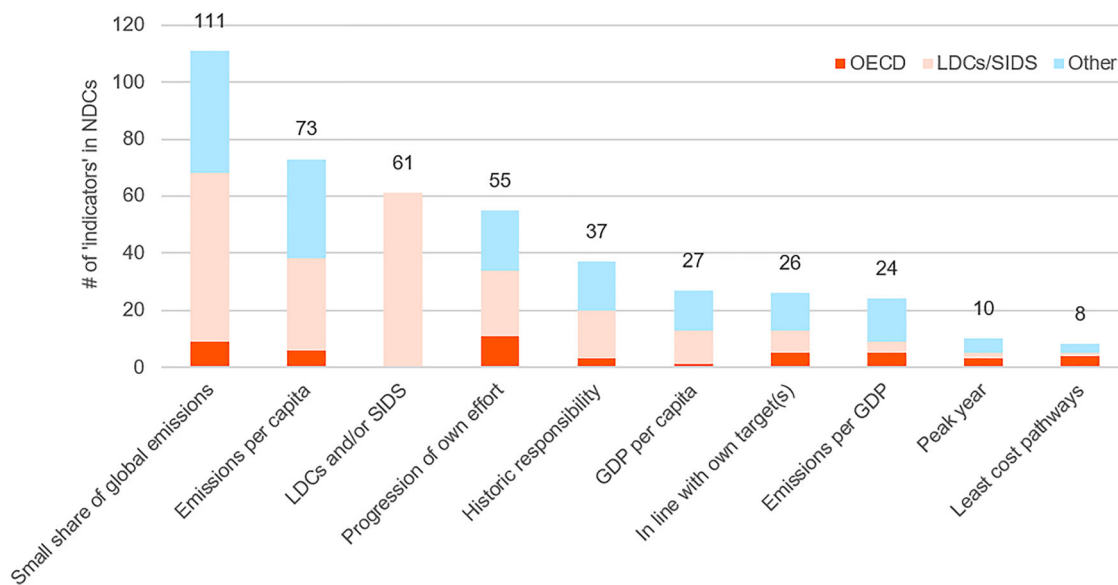


Figure 3. Direct references to indicators of equity in 168 NDCs submitted as of 31 December 2020.

- principles – both those identified within the general narrative context of a state’s NDC, as well as in justifying the fairness of their contribution (UNFCCC, 2019b, Annex I, para 6). Explicit references to particular principles, whether characterized as principles or not, are listed. For instance, references to ‘sustainable development’ or ‘common but differentiated responsibilities’ are included even if the term ‘principle’ has not been used in association with that phrase. Implicit references to principles, as for instance where the elements commonly identified as comprising the principle are referred to, are also listed. For instance, where a state refers to vulnerability it arguably supports the principle of special circumstances.
- objective indicators through which principles are operationalized. The subjectively selected objective indicators that states have identified and applied to justify the fairness of their contributions are listed.
- ‘progression’, ‘highest possible ambition’ and ‘best available science’ (UNFCCC, 2015, Article 4.3, 4.1 and 14).
- the long-term temperature goal (UNFCCC, 2015, Article 2.1(a)).
- human rights (UNFCCC, 2015, preambular recital 11).

In tabulating these references in the NDCs, this article starts with an existing dataset (Winkler et al., 2018) that records references to objective indicators in the NDCs. It first updates this dataset in relation to indicators and then extends it to include the data listed above. The dataset covers 168 NDCs, of which 41 are revised NDCs (the cut-off date was 31 December 2020). In what follows, this article sifts through the data to analyse its implications for the quantification of national fair shares. Extensive discussions of each principle and concept are precluded by space limitations, but the insights below build on a vast body of existing literature on the emerging legal status and operational relevance of principles of international environmental law in this field (Brunnée et al., 2021b; Krämer & Orlando, 2018).

Some of these principles address effort sharing and are thus directly engaged in *determining* fair shares. These include principles relating to sustainable development, common but differentiated responsibilities, special circumstances and equity. Others, such as the principles relating to harm prevention and precaution, address decision-making on environmental harm and are salient in *interpreting* fair shares, and in narrowing the range of fair shares that follows an application of the equitable principles of international environmental law. In addition, the references to highest possible ambition, progression and best available science – play an influential role in interpreting and narrowing the range of fair shares in service of the long-term temperature goal in Article 2.1 (a) of the Paris Agreement. The principles of international cooperation, public participation and good faith are relevant in *implementing* fair shares. Although, for conceptual clarity we categorize principles into three baskets based on the functions they perform – determination, interpretation and implementation – there is dynamic interplay between all these principles, and taken together they fill some of the normative gaps in international environmental law. Figure 1 reflects the results both of the dynamic interplay between these three sets of principles and norms, as well as the indicators these principles support (and do not).

2.3. Principles engaged in determining fair shares

The principles engaged in determining fair shares are frequently referenced in national court decisions. In the broader context of determining the adequacy of national climate action against a state’s fair share, courts have highlighted the principle of sustainable development (Supreme Court of Nepal, 2018), principle of common but differentiated responsibilities (Administrative Court of Berlin, 2019, p. 71 and 78; District Court of The Hague, 2015, paras 2.36, 2.38; Supreme Administrative Court of France, 2020; Supreme Court of Ireland, 2020; Supreme Court of the Netherlands, 2019, para. 7.3.2), and equity, intra and/or intergenerational (Land and Environment Court, New South Wales, 2019, para. 406 and 415; Supreme Court of Colombia, 2018, para. 10 and 11.3). This section considers these and related principles with a view to categorizing the indicators used by states in justifying their NDCs into those that are supported by principles of international law, and those that are not.

Sustainable development: The principle of sustainable development defined as ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs’ (World Commission on Environment and Development, 1987; United Nations, 1992a, in particular principle 4

(integration) and 5 (poverty eradication); ILA, 2014), is by far the most frequently invoked by states in their NDCs. The NDCs contain 136 explicit (representing 81% of NDCs) and 8 implicit references to sustainable development. Sustainable development is recognized as including elements of economic development, social development, environmental protection and sustainable use and management of natural resources, with the emphasis moving over time towards integration of environmental protection and sustainable use into social and economic development goals (ILA, 2014, Draft Article 3, p. 10, para. 4). The concrete content of sustainable development is determined by the evolving customary and treaty norms of environmental protection (Viñuales, 2020). In this sense it is a norm in flux as well as intricately connected to other norms and principles.

In the climate change regime the normative centrality of the principle of sustainable development is undisputed. There are numerous references to sustainable development including in operational provisions of the treaties comprising this regime (UNFCCC, 1998, Article 12, 2015, Article 2, 3, 4; United Nations, 1992b, Article 3.4). References to sustainable development in the climate change regime are frequently accompanied by references to poverty eradication (UNFCCC, 2015, Preambular recital 8, and Article 2.1 and 4.1; United Nations, 1992b, Preambular recital 21 and Article 4.7), which shape the principle's content and focus. Efforts to distil the core content of sustainable development beyond this, and operationalize it, however, have been less successful. FCCC Article 3 contains a 'right to promote sustainable development', a compromise between developed and developing states that began as an ask from developing states for a 'right to development' (Rajamani, 2018b). This evolved in the 2010 Cancun Agreements, at the behest of the BASIC states, into a recognition of 'equitable access to sustainable development' (UNFCCC, 2010, para. 6; Winkler et al., 2011, 2013).

Dynamic interplay with other principles: Sustainable development is inextricably linked with other principles relating, inter alia, to:

- harm prevention, since sustainable development derives concrete content from norms of environmental protection (International Court of Justice, 1997, para. 140, 2010, pp. 75–77);
- equity, since, by definition, sustainable development requires a balance between equity across and within generations;
- common but differentiated responsibilities, as sustainable development captures a concern with equity within the same generation;
- Special circumstance, as vulnerability intersects with economic disadvantage and reflects levels of social and economic development; and,
- international cooperation, as sustainable development is best promoted in a supportive international economic system (see for instance UNFCCC, 1998, Article 12; United Nations, 1992a, Principles 9 and 12).

Indicators: The principle of sustainable development supports the consideration of indicators that shed light on levels of economic and social development, hence among the indicators listed by states, GDP per capita (27), and classification as small island developing states (SIDS) or least developed countries (LDCs) (61) are supported. Among the indicators in the literature, those relating to 'basic needs' and the human development index are supported.

Special circumstances: This principle requires that the special circumstances and specific needs of developing states, especially those that are least developed, and particularly vulnerable, be given priority, and/or full consideration (ILA, 2014, Draft Article 6; UNFCCC, 2015, preambular recital 5 and 6; United Nations, 1992a, principle 6, 1992b, Article 3.2). 122 NDCs contain explicit (representing 73% of NDCs) and 4 contain implicit references to special circumstances. This principle is, by definition, open-ended as circumstances and needs are context and country specific. However, this principle includes elements relating to environmental vulnerability and economic and social development, which provides qualitative criterion for distinguishing not just between developed and developing states, but also between developing states (ILA, 2014, Draft Article 6, Commentary, p.13).

Dynamic interplay with other principles: The principle of special circumstances is closely linked to other principles, including:

- sustainable development, as discussed above;

- common but differentiated responsibilities, since it also provides criteria for differentiating between states;
- equity, in so far as prioritizing the needs of least developed and vulnerable states enhances equity within and between generations; and,
- international cooperation, as the loss and damage that accompanies vulnerability is a recognized subject of international cooperation (UNFCCC, 2015, Article 8)

Indicators: The principle of special circumstances supports consideration of indicators that shed light on environmental vulnerability and economic and social development, hence among the indicators listed by states, the following indicators are supported: classification as SIDs or LDCs (61), and GDP per capita (27). Other indicators may be relevant but have not been listed in the NDCs. The indicator relating to ‘share of global emissions’ which 111 NDCs refer to, is *only* relevant to the extent that it overlaps with environmental vulnerability, and economic and social disadvantage.

Common but differentiated responsibilities: This principle, oft-cited in literature and by states, is referred to explicitly in 59 NDCs (representing 35% of NDCs), and implicitly in 18. It recognizes that states have common but differentiated responsibilities in addressing environmental harm (United Nations, 1992a, principle 7, 1992b, Article 3(1); ILA, 2014, Draft Article 5). The ‘common’ element in this principle signals that environmental protection is a matter of ‘common concern’ and requires efforts by all. The basis for differentiated responsibilities, however, is disputed. In Rio Principle 7, responsibilities are differentiated ‘in view of different contributions to global environmental degradation’, but FCCC Article 3 does not specify the basis for differentiation. Instead, it adds the element of ‘respective capabilities’ to the principle. Although this addition is reflective of particular negotiating politics, the basis of differentiation is plausibly both differing contributions to environmental harm (and thus responsibilities, historical, current and projected) as well as differing capabilities to address it (Rajamani, 2018a). The Paris Agreement added a further element – ‘in light of different national circumstances’ – to the climate regime’s articulation of the principle of common but differentiated responsibilities. Arguably the qualification of the principle by a reference to ‘national circumstances’ introduces a dynamic element to the interpretation of the principle, i.e. as national circumstances evolve so too will the common but differentiated responsibilities of states (Rajamani, 2017). In any case, the principle has been interpreted to require developed country leadership in addressing environmental and climate harm (United Nations, 1992b, Article 3; and by implication from UNFCCC, 2015, Articles 3, and 4.4).

Dynamic interplay with other principles: The principle of common but differentiated responsibilities is closely linked with other principles, including:

- sustainable development, as indicated above;
- special circumstances, as indicated above;
- international cooperation, since the ‘common concern’ element of the common but differentiated responsibilities principle requires individual, cooperative, and collective efforts in service of the environmental goal; and,
- equity, since the common but differentiated responsibilities principle addresses intra-generational equity.

Indicators: The principle of common but differentiated responsibilities supports consideration of indicators that speak to common concern, responsibilities and capabilities, hence among the indicators in the NDCs the following are supported: historic responsibility (37), emissions per capita (73), GDP per capita (27), and classification as SIDS or LDCs (61). In addition, other indicators such as cumulative GHG emissions relating to historical responsibility and, current and projected environmental harm are also relevant considerations in the application of this principle.

Equity: The principle or notion of equity is referred to explicitly in 50 NDCs (representing 30% of the NDCs) and implicitly in 2. Although the term equity is often used inter-changeably with common but differentiated responsibilities in the climate change regime, it is a wider notion that encompasses arguments based on fairness, justice, equality (for equals), affirmative action, redistribution, and restoration (Rajamani, 2017; Shue, 1999). Notwithstanding definitional and boundary challenges, equity is a fundamental part of international law. In the absence of clearly defined rules, judges frequently rely on ‘principles and techniques’ of equity to

interpret, fill gaps, and even to remedy inadequacies in the law (Lowe, 1992). Equity finds reference in numerous principles of international environmental law, as for instance in the context of the ‘right to development’ (United Nations, 1992a, Principle 3), and in international climate change law in the context of ensuring fair effort-sharing (UNFCCC, 2015, Articles 2.2, 4.1 and 14.1; United Nations, 1992b, Article 3.1). Although there are few persuasive definitional attempts, it is generally recognized as consisting of two elements – intra-generational equity, which overlaps with common but differentiated responsibilities, and inter-generational equity. The intra-generational element has developed along several lines in the climate change regime including: ‘equitable access to sustainable development’, development and poverty eradication (UNFCCC, 2010, para. 6, 2015, preambular recital 8), equity or principle-based reference framework (UNFCCC African Group, 2013), recognition of the need to address the loss and damage suffered by vulnerable states (UNFCCC, 2015, Article 8), and in relation to the global stock-take (UNFCCC, 2015, Article 14.1, 2019a, decision 3/CMA.1, 2019b decision 4/CMA.1, Annex I; Winkler, 2020). The inter-generational element is less developed, but finds explicit reference in the FCCC (United Nations, 1992b, Article 3.1), and arguably implicit expression in the drivers of ambition and urgency in the Paris Agreement (UNFCCC, 2015, preambular recital 4, Article 4.3), the references to human rights of children (UNFCCC, 2015, preambular recital 11), and the long-term temperature goal (UNFCCC, 2015, Article 2.1(a)). Inter-generational aspects have proven determinative in recent climate litigation before national courts (Federal Constitutional Court of Germany, 2021; Federal Court of Australia, 2021). Indeed, the Australian Federal Court characterized climate change as the ‘greatest inter-generational injustice ever inflicted by one generation of humans upon the next’ (Federal Court of Australia, 2021). Further, inter-generational aspects are being increasingly referenced by youth claimants in climate litigation before national (South Korean Constitutional Court, 2020; United States 9th Circuit Court of Appeals, 2020) and regional courts (European Court of Human Rights, 2020a).

Dynamic Interplay with other principles: The principle of equity, given its open-ended nature, is closely linked with other principles, including:

- Sustainable development, in its expression as ‘equitable access to sustainable development’;
- Common but differentiated responsibilities, since it overlaps with intra-generational equity;
- Special circumstances, as indicated above; and,
- International cooperation, as the provision of support, financial, technological and others to developing states, is an expression of equity.

Indicators: The principle of equity supports consideration of indicators that shed light on aspects of inter-generational and intra-generational equity, hence among the indicators listed by states the following are supported: historic responsibility (37), emissions per capita (73), GDP per capita (27), classification as SIDS or LDCs (61). In addition, other indicators such as cumulative GHG emissions, GDP per capita adjusted for development threshold (Holz et al., 2018) and are also relevant considerations in the application of this principle.

Collectively the relevant principles of international environmental law engaged in *determining* fair shares support the consideration of the following indicators: emissions per capita (73), GDP per capita (27), classification as LDCs and/or SIDS (61), historic responsibilities (37), and small share of global emissions (111) but *only* where it overlaps with special circumstances (i.e. LDCs and/or SIDS) (59).

2.3.1. Indicators not supported by the equitable principles of international environmental law

Some NDCs contain indicators, offered by states as part of their narrative justification, that are *not* anchored in the equitable principles of international environmental law. These include: small share of global emissions for states that are not LDCs and SIDS (52), least cost pathways (8), emissions per GDP (24), progression of own effort (55), in line with own targets (26) and peak year (10).

That a state’s emissions are a small share of global emissions, offered as justification by 52 states that are not LDCs or SIDS, is not in accordance with the principles of international environmental law. Principles of international environmental law build on the understanding that the environment is a matter of ‘common concern’ and that all states, ‘big and small’ (United Nations, 1972, principle 24) ‘cooperate in a spirit of global partnership’ to restore the environment (United Nations, 1992a, principle 7). National court decisions

have also rejected the argument that a small share of emissions, whether from a mining project (Land and Environment Court, New South Wales, 2019) or a state, justifies continuation of those emissions or limits the action that needs to be taken (Federal Constitutional Court of Germany, 2021, paras 202–203; Supreme Court of the Netherlands, 2019, paras 5.7.7–5.7.9). Justice Preston noted in *Gloucester Resources* that, ‘climate change is caused by cumulative emissions from a myriad of individual sources, each proportionally small relative to the global total of GHG emissions, and will be solved by abatement of the GHG emissions from these myriad individual sources’ (Land and Environment Court, New South Wales, 2019, para. 516). This passage was quoted approvingly in the March 2021 Canadian Supreme Court decision upholding the constitutionality of Canadian federal carbon pricing legislation (Supreme Court of Canada, 2021).

‘Least-cost pathways’ form part of the justification for 8 NDCs. While identifying a least cost pathway may be a relevant consideration in choosing between alternative means of implementing national fair shares, it is not a relevant consideration in *determining* fair shares. As some scholars argue, imposing a least cost solution in a highly unequal world is ‘inherently unjust’ (Dooley et al., 2021). The precautionary principle requires measures to be taken, even in the absence of full scientific certainty, and these measures need to deliver ‘global benefits at the lowest possible cost’ (United Nations, 1992b, Article 3.4). In the context of climate change, there is overwhelming scientific certainty (IPCC, 2018b), and in any case, as discussed below, the precautionary principle is opposed to a simple cost–benefit analysis. Cost may, however, play a role in operationalizing and implementing fair shares, and the principle of cooperation, discussed below, supports for instance, market-based approaches to emissions reductions that lower the global costs of mitigation.

Some states have also identified emissions per GDP (24), ‘progression of own effort’ (55), ‘in line with own targets’ (26) and a ‘peak year’ (10) in their NDCs as part of their fairness justifications. These indicators explain the pragmatic choices that state make and how they plan to achieve their NDCs, including in line with normative expectations under the Paris Agreement. They do not, however, justify the fairness of a state’s NDC. ‘Progression of own effort’, responds to one of the normative pillars of the climate change regime, and is linked to the harm prevention principle, and is therefore on a different footing to the rest of the indicators identified in this section. Even so, progression is not an indicator of fairness unless that progression is pegged to an attempt to close the gap from where a state is to where it ought to be in terms of its fair share. Further, the pragmatic choices some states make in selecting their NDCs based on current emissions levels (‘grandfathering’) and in charting an extended mitigation pathway that privileges current (high) levels, and may even maintain the current uneven distribution of emissions across nations (‘constant emissions ratios’), finds no justification in the equitable principles of international environmental law. Quite the contrary. The principles of sustainable development, common but differentiated responsibilities, and equity, read in the light of the normative framework of the UN climate treaties, recognize that current levels of emissions in some states are high (United Nations, 1992b, preambular recital 3) and in others emissions may need to grow to achieve sustainable development, and eradicate poverty (United Nations, 1992b, preambular recital 22, Art. 4.7; UNFCCC, 2015, preambular recital 8, and Articles 2.1 (chapeau), and 4.1). Grandfathering or maintaining constant emission ratios arguably creates ‘cascading biases’ against poorer states (Kartha et al., 2018), is not a ‘standard of equity’ (Dooley et al., 2021), and is indeed morally ‘perverse’ (Caney, 2011). It is also a well-established principle of common law that no person ought to profit from their own wrong (Dworkin, 1967). It is worth noting that international legal accountability for historical emissions hinges on whether such emissions were internationally wrongful acts at the time. However, selecting a share of emissions reduction effort based on models that privilege current and past high levels of emissions and that may even lead to a continuation of uneven shares is an ongoing (not a historical) wrong.

2.4. Principles and norms engaged in interpreting fair shares (and narrowing the range)

In addition to the principles that are directly engaged in the determination of fair shares, other principles of international environmental law and normative pillars of the climate change regime, play a role in *interpreting* fair shares. Given the open-ended nature of principles and their loose translation into operational indicators, applying these indicators to quantify national fair shares yields a wide range ‘fair shares’ for each state. If states undertook only to deliver on the minimum of their fair share, the international community will not

collectively deliver on the long-term temperature goal identified in the Paris Agreement (UNFCCC, 2015, Article 2.1(a)). The minimum fair share within the range therefore represents a *floor* below which a state's NDC must not fall. All states, however, must do much more than their minimum fair share to bridge the gap. This conclusion follows from the application of further principles of international environmental law as well as the normative pillars of the climate change regime.

Two principles of international environmental law, not reflected explicitly in the NDCs but nevertheless salient, play a role here, namely harm prevention and precaution. While reflection of a principle in the NDCs strengthens the case for their particular application in the climate change regime, given the general character of these principles, especially harm prevention as custom, they perform important contextual and interpretative functions. This is supported by the fact that national courts rely on these principles (Kotzé et al., 2021). In their deliberations on the appropriate level of action for a state to take, national courts have invoked both the harm prevention principle (implicit in Supreme Court of Colombia, 2018, para 11.3; Supreme Court of the Netherlands, 2019, paras 5.7.2, 5.7.5, 7.3.2) and precaution (Court of Appeal of the United Kingdom, 2020, paras 258–259; Federal Court of Australia, 2021; Federal Constitutional Court of Germany, 2021; High Court of New Zealand, 2017, paras 88–94; Supreme Court of Colombia, 2018, para. 11.1; Supreme Court of the Netherlands, 2019, paras 5.7.3, 7.2.5, 7.2.10).

The *harm prevention principle* imposes a responsibility on states 'to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction' (United Nations, 1972, Principle 21, 1992a, Principle 2). Harm prevention is a binding rule of customary international law (International Court of Justice, 1996, 1997, 2010, 2015). This rule imposes on states an obligation of conduct, rather than of result, subject to the exercise of 'due diligence' (Brunnée, 2021a). Due diligence is a 'variable' concept that is shaped by evolving scientific and technical knowledge, as well as the risks involved in the activity (ITLOS, 2011, para. 117). The standard of due diligence expected of states in the climate regime therefore has to be determined with reference to numerous factors including the objective of the climate change regime and the nature of the harm that would be suffered in the absence of due diligence (Rajamani, 2020). Due diligence required of states must be 'appropriate and proportional to the degree of risk of the transboundary harm' (ILC, 2001, commentary to Draft Article 3, para 11). The enormous risk of potentially irreversible climate impacts at temperatures above 1.5°C (IPCC, 2018b) suggests a correspondingly high standard of due diligence. In the context of interpreting national fair shares, therefore, the harm prevention principle creates a strong pull towards more stringent targets within the range of fair shares.

The risk of irreversible climate impacts also engages the *precautionary principle* to the extent that there remains scientific uncertainty on climate impacts. The precautionary principle states that if there are 'threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation' (United Nations, 1992a, Principle 15, 1992b, Article 3.3). Although there are different views on the level of scientific uncertainty sufficient to override arguments for postponing measures as well as the significance of environmental harm at stake (Peel, 2021), with respect to climate change both thresholds are readily met. There is overwhelming scientific certainty on the causes and consequences of climate change, with much of the remaining uncertainty focused on speed, extent and feedback loops in terms of impacts. The reference to 'cost-effective measures' is interpreted to favour the least-cost option among alternatives (Geistfeld, 2001, pp. 11326, 11327), with the principle opposed to a simple cost-benefit analysis (Peel, 2021). In the context of interpreting fair shares therefore, the precautionary principle also creates a strong pull towards more stringent targets within the range of fair shares.

In addition to these two principles, three sets of norms in the climate change regime exert a strong pull towards more stringent targets within the range of fair shares. The first is the *objective* of the climate change regime to hold the temperature increase to 'well below 2°C' and strive towards '1.5°C' above pre-industrial levels (UNFCCC, 2015, Article 2.1(a), a development of the stabilization goal in United Nations, 1992b, Article 2). Although the Paris Agreement does not impart specific legal force to the temperature goal in its application to the actions of individual states, it is a benchmark against which Parties' collective efforts could be tracked through the global stock-take, and against which each Party could set and calibrate its own mitigation

efforts (Rajamani & Werksman, 2018). That states recognize this effect of the temperature goal is evident from the fact that 127 states (representing 76% of NDCs) refer to the temperature goal in their NDCs. The temperature goal is referred to and even used by some national courts as a benchmark against which national efforts and approaches can be set and calibrated (Court of Appeal of the United Kingdom, 2020, para. 185; Federal Constitutional Court of Germany, 2021, para. 159; Land and Environment Court, New South Wales, 2019, para. 697; Supreme Court of the Netherlands, 2019, para. 7.2.8). In the ongoing Portuguese children's case the claimants argue that states' 'fair share' must be read in light of their human rights obligations and the long-term temperature goal such that their collective implementation limits global warming to the agreed level (European Court of Human Rights, 2020a, para. 29).

The second set of norms that creates a strong pull towards more stringent targets, includes, the expectation of progression and 'highest possible ambition' in successive NDCs (UNFCCC, 2015 Article 4.3). The Paris Agreement, built as it is on nationally determined rather than multilaterally negotiated contributions, relies on iterative increases in ambition to progressively bridge the gap between the sum of individual contributions and collective goals (Rajamani & Brunnée, 2017; Voigt & Ferreira, 2016). That States recognize the normative salience of these notions in guiding their contributions is evident from the fact that 122 states (representing 73% of the NDCs) refer to one or more of these normative pillars in their NDCs. Both 'progression' and 'highest possible ambition' also shape the due diligence standard for states under the harm prevention principle discussed earlier.

The third set of norms that creates a strong pull towards more stringent targets are norms relating to *human rights*. Albeit preambular, the Paris Agreement is the first multilateral environmental agreement to contain an explicit reference to human rights (Knox, 2020). While the legal effect and influence of this recital is disputed (Boyle, 2018; Duyck et al., 2018; Mayer, 2016; Rajamani, 2018b), the integration of human rights concerns into the climate change regime cannot but have a salutary effect on ambition. Climate impacts at all levels of temperature increase pose a serious risk to the rights to life, health, food, and an adequate standard of living for individuals and communities across the world, with more pervasive and irreversible impacts at higher levels of temperature increase. An approach that recognizes the human rights implications of climate impacts thus favours higher levels of ambition and lower levels of temperature increase. Individual human rights are threatened even at levels below 1.5°C. The normative salience of human rights norms in driving ambition is in evidence in the NDCs where 87 (52% of NDCs) states refer to human rights. The human rights dimension is also attentive to equity between and among peoples and groups within nations. An increasing number of cases are being brought in national, regional and international courts by claimants arguing that climate impacts violate their human rights to life and health, among other rights (Peel & Osofsky, 2018; Savaresi & Auz, 2019; Yoshida & Setzer, 2020). In the Portuguese children's claim filed against 33 European states, the claimants argue that their rights to life and private life and home under Article 2 and 8 of the European Convention on Human Rights are threatened by these states' inadequate climate action (European Court of Human Rights, 2020a; Liston, 2020).

The cumulative effect of the principles and norms discussed in this section is to require a significant narrowing of the range of fair shares for each state, so as to bridge the gap between the sum of current NDCs and that which is required to meet the Paris Agreement's long-term temperature goal.

2.5. Principles engaged in implementing fair shares

A final set of principles relevant in implementing national fair shares includes the principle of cooperation, public participation and good faith. While there is dynamic interplay between all the principles of international environmental law, there is a conceptual distinction between those principles that are relevant in *determining* fair shares and those relevant in *interpreting* and *implementing* them.

The principle of cooperation, referred to explicitly in 101 NDCs (representing 60% of NDCs) and implicitly in 49, is well established in international law as offering normative direction to states on matters requiring collective action (Delbrück, 2012; ILC, 2014, Article 8; United Nations, 1972; Wolfrum, 2012). It is also recognized as central to the harm prevention principle discussed earlier (ILC, 2001, pp. 155–156). Cooperation takes many forms in international environmental law, including information sharing, financial assistance, technology transfer, capacity-building and cooperative market-based approaches. These cooperative measures have the

potential to advance global environmental and development goals, to deliver global mitigation benefits at lower cost, and to contribute towards meeting a state's fair share of the global mitigation effort. The principle of public participation referred to explicitly in 86 NDCs (representing 51% of NDCs) and implicitly in 28, underscores the importance of public participation in decision-making, access to environmental information and provision of effective access to judicial remedies (Ebbesson, 2021; United Nations, 1992a, Principle 10). This principle applies in the domestic processes engaged in arriving at national contributions, rather than in determining fair shares between states. The principle of good faith, and the 'spirit of partnership' underpin the entire international legal system and is central to the climate change regime (ILA, 2014, Draft Article 8; United Nations, 1992a, Principle 27; Shibata, 2021). There is a strong normative expectation that all states will pursue the ultimate objective of the FCCC and the long-term temperature goal in good faith and in a spirit of partnership.

3. Quantifying fair-share contributions based on principles of international environmental law

3.1. Categorizing quantification approaches based on principles of international environmental law

This section seeks to translate the findings emerging from section 2 – on the extent to which particular indicators identified by states in their NDCs accord with principles of international environmental law – into quantitative assessments of fair shares.

Such a quantitative approach is valuable in that it enables a comparison and benchmarking of national emissions targets against fair share ranges anchored in principles of international environmental law. However, it also comes with limitations. Some elements of the principles of international environmental law do not lend themselves readily to quantitative expression. Other elements lend themselves to such expression but have not yet been so expressed in the literature. Should further elements be quantified and added to the models, the impact on the fair share ranges, particularly for some states will be significant. For example, the literature

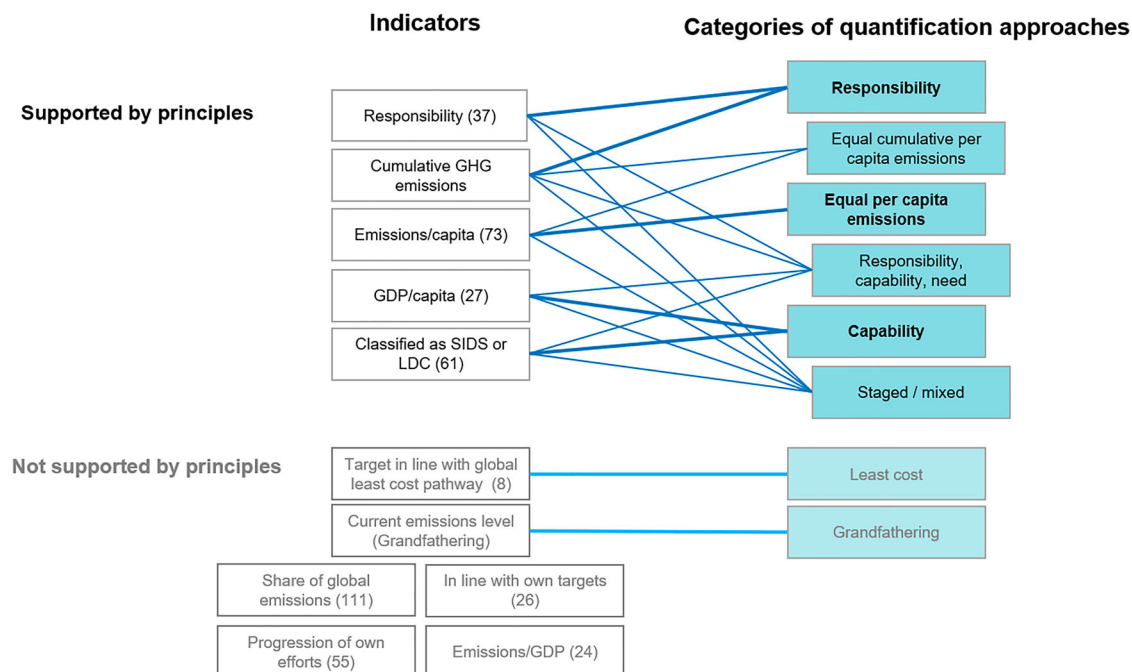


Figure 4. Mapping of indicators (white boxes) and quantification approaches of effort sharing (blue boxes). Numbers in brackets indicate the number of NDCs in which a principle or indicator is mentioned.

does not currently address the special circumstances of Small Island Developing states. Additional elements in their case could lead to significantly different results. The results presented in this section therefore are useful, particularly for larger states as sufficient results are available to define the range, but are not comprehensive as it is not possible to include all principles in a quantitative assessment.

Section 3 first compares the collected and categorized literature on quantitative estimates of effort sharing used in the Fifth Assessment Report of the IPCC (Clarke et al., 2014; Höhne et al., 2014) and checks whether the approaches listed there include all the indicators mentioned by states in their NDCs, and whether these indicators withstand a test against the principles of international environmental law (Figure 4). Most categories used in previous work clear the test, but some categories of approaches and some ways in which particular approaches have been implemented do not.

The following categories of quantification approaches are based on indicators consistent with the principles of international environmental law discussed above (section 2), and thus the results of these approaches are included in our analysis.

- **Responsibility:** Approaches in this category usually take cumulative historical GHG emissions as an indicator for historical responsibility and assume that a country with higher historical emissions needs to reduce emissions more.
- **Capability:** Approaches in this category usually use indicators such as GDP per capita or the Human Development Index and assume that states with higher values have a higher capability to reduce emissions and should do so. The ‘basic needs’ principle is also considered in this category because it can be considered an expression of the capability principle – least capable states could be permitted a less ambitious reduction effort to secure their basic needs.
- **Responsibility, capability and need:** Approaches in this category emphasize historical responsibility, capability and the need for sustainable development. They use a combination of the indicators listed in the previous categories.
- **Equal per capita emissions:** This approach, pervasive in the quantification literature, allocates equal emission rights per person either immediately or assumes convergence over time. This approach is premised on the ‘egalitarian’ principle that every human being is entitled to the same atmospheric space. While it is not directly anchored in principles of international environmental law, it arguably finds support in human rights instruments and approaches.
- **Equal cumulative per capita emissions:** Approaches in this category combine per capita equality with responsibility (cumulative accounting for historical emissions) to allocate emission levels based on total national carbon budgets.
- **Staged approaches:** Staged approaches combine indicators to determine levels of reductions for groups of states that are staggered in time based on status or circumstances. For example, under a ‘common but differentiated convergence’ approach, developed states are expected to begin a transition toward equal per capita emissions before developing states. These approaches combine various elements and therefore are based on almost all of the indicators identified.

Some indicators and/or categories of approaches used in earlier analysis have been excluded from this analysis as they are not supported by principles of international environmental law (as discussed above). These are:

- **Least-cost:** Some approaches allocate emissions reduction targets (in part) based on mitigation potential or the reduction of emissions where it is globally the cheapest. Some also assume equal percentage GDP loss. This category also includes approaches that contain elements of cost-effectiveness in that those with high specific emissions (i.e. high potential for reductions) have to reduce more, e.g. Triptych approach (Phylipsen et al., 1998) or approaches that combine costs with capability, e.g. assume equal cost per GDP. As explained in section 2, while least cost approaches are relevant in *implementing* fair shares, they are not relevant in the *determination* of fair shares.

- Grandfathering: Almost all quantification approaches start from a historical national emission level and as such include some element of ‘grandfathering’, but some approaches rely on grandfathering more than others. Those approaches that take a late starting point (e.g. (van den Berg et al., 2020) takes emissions of 2020 as the starting point) or perpetuate the status quo after 2050 (converging per capita emissions by 2100) are excluded (see supplementary information for a list of studies and approaches).

3.2. Data and analysis steps

This section estimates fair share emission levels for individual states based on over 40 available studies, including data published in the last few years (see supplementary information). From these available studies and approaches, only those that provide robust and meaningful data input are selected. Emissions from all greenhouse gases are included, but emissions from Land Use, Land Use Change and Forestry (LULUCF), characterized by significant uncertainties, are excluded. Therefore, studies that determine fair shares only on the basis of energy CO₂ and do not cover non-CO₂ emissions are excluded. Also excluded are studies and results where the emissions including LULUCF strongly impact the result. Only studies that use a global emissions target pathway that is within the range of ‘well below 2°C’ compatible emissions pathways achievable today are included. This excludes some older studies that assumed reductions in the last 10 years and a correspondingly higher emission level in 2030 or 2050.

For each state, the preliminary fair share range is determined using input data from *all* allocation approaches, including those approaches that rely on indicators that are not supported by principles of international environmental law. The 5th to the 95th percentile is used as the preliminary fair share range, so that all studies *influence* the positions of the fair share range but extreme cases do not explicitly set the range

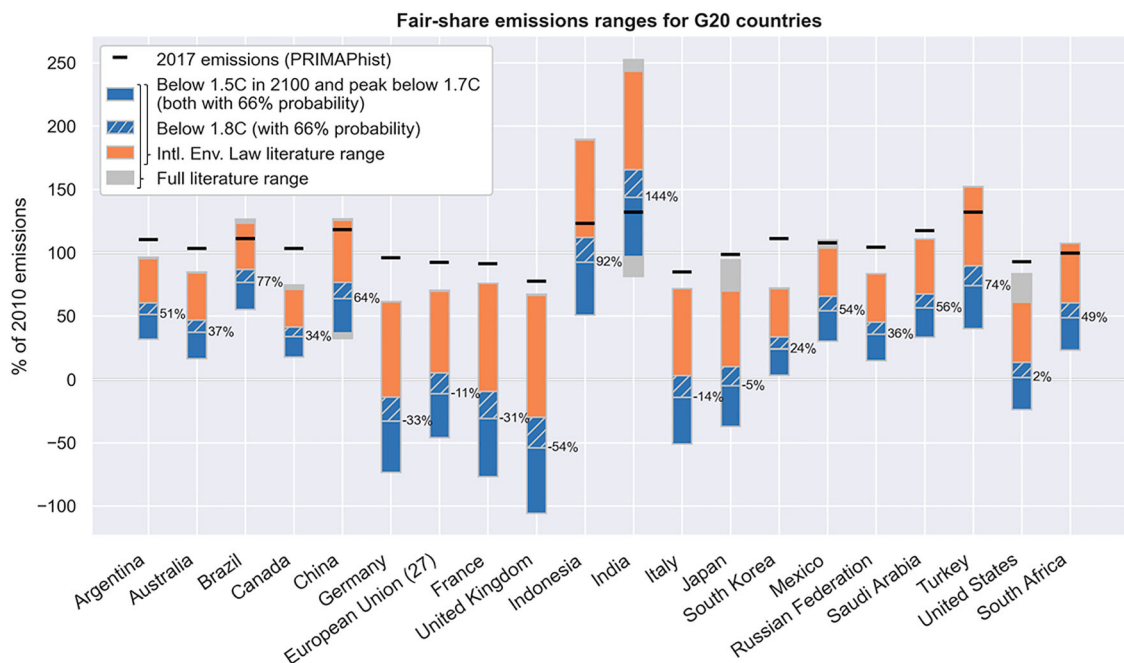


Figure 5. Emissions relative to 2010 levels that are consistent with the literature: all approaches, including those not in line with principles of international law (grey), reduced according to those compatible with principles of international environmental law (orange and blue), and those that would ensure aggregate emissions remain below 1.8°C throughout the century (hashed blue) or remain below 1.7°C and are below 1.5°C in 2100 with 66% probability (blue). 2017 emissions levels (black dash, PRIMAPHist, Gütschow et al., 2016) are shown to indicate direction of change in the last decade. Emissions include all greenhouse gases but exclude land use change and forestry and international bunker emissions. Results shown here for G20 states only; additional results can be found in the supplementary material.

(Figure 5). This reduces the impact of spurious data points in an automatic manner, which is a challenge when dealing with all states and multiple studies. When determining the 5th and 95th percentile, datapoints are weighted so that each category (see section 3.1) has the same total weight, which eliminates a bias towards categories that are studied more than others. For the impact of this assumption and alternative methods see Ganti et al. (n.d.).

Next, those studies and approaches that are anchored in principles of international environmental law are separated from those that are not (grey area in Figure 5) to arrive at the fair share range. Even after thus reducing the range, if all states were to achieve only the least ambitious end of their fair share emissions range, emissions would exceed the level needed to meet the Paris Agreement's temperature goal. If all states were to choose the least ambitious end of their fair share range, total emissions would equal 63 GtCO₂e, excluding LULUCF and bunkers, which is factor 2–3 higher than required for 'well below 2°C' or 1.5°C.

To ensure that the Paris Agreement's long-term temperature goal is met, in keeping with the principles of harm prevention and precaution, and the normative pillars of the climate change regime, as discussed in section 2, the range will need to be further compressed. Since the indicators relevant to *determining* fair shares have already been taken into account in arriving at this fair share range, from this point on all states are treated the same. The range of fair shares can be reduced in line with the desired temperature goal by starting from the top end of each state's fair share range and moving down the fair share range of each state by the same percentage until the aggregate over all states reach the emission level that is consistent with a temperature level. This approach was first used elsewhere (Climate Action Tracker, 2015) and is also described in Ganti et al. (n.d.).

A prerequisite here is the determination of a global emission level in 2030 that is consistent with holding warming to 'well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels'. The Paris Agreement's temperature goal in Article 2.1(a) is a single goal with two textually linked temperature limits (Mace, 2016; Rajamani & Werksman, 2018). The goal, albeit captured in an operational provision of a binding treaty, is phrased in aspirational terms. Although the goal does not lend itself to enforcement, it represents a clear intent to instil urgency and ambition in efforts to address climate change (Rajamani & Werksman, 2018), and to provide a direction and pace of travel (Mace, 2016). There is a good faith expectation that Parties will take steps towards meeting the long-term temperature goal identified in the Paris Agreement. The numerous references to the goal in Parties' NDCs, as discussed in section 2, bolsters this interpretation and expectation.

This article relies on the 2019 UNEP Gap report's categorization of scenarios to derive a global emission level to reduce the fair-share range for each state. The UNEP gap report provides a selection of mitigation pathways from the IPCC's SR 1.5 report that have a two-thirds (66%) chance of keeping temperature below 1.8°C by 2100, which is considered here as consistent with 'well below 2°C'. Median global emissions in 2030 for this category are 35 GtCO₂e (Table 3.1 in UNEP, 2019). Henceforth in this article, this category is labelled 'well below 2°C'.

The UNEP Gap Report also identifies scenarios that keep warming below 1.5°C in 2100 with a peak below 1.7°C (both with >66% probability). Here the median pathway has total global emissions of 25 GtCO₂e in 2030 (Table 3.1 in UNEP, 2019).

The next step is to move down the fair share range for every state by the same percentage until the global emission level for 'well below 2°C' is reached (border between orange and blue striped in Figure 5), and then further until the 1.5°C level is reached (border between blue striped and blue in Figure 5).

In this article, national emissions are distributed but LULUCF and emissions from international aviation and shipping and land-use are excluded, and therefore these emissions need to be subtracted from the total amount in 2030 allowable to states' targets. Arguably aviation and shipping should also meet their fair-share but determining what that should be and how it should be distributed has thus far proven challenging. This article therefore does not allocate emissions from these sectors to states and takes a current policy scenario for these sectors (total of 1730 MtCO₂), which is the median of the 710–840 MtCO₂ for aviation and 870–1040 MtCO₂ for shipping in 2030 from (Climate Action Tracker, 2020a, 2020b).

The 2019 UNEP Gap report does not provide emissions from LULUCF separately, so the AFOLU CO₂ emissions from the closest matching scenario category in the SR1.5 report are taken here. For the 'well below 2°C' range, this corresponds to the 'Lower-2°C' scenarios which range from 0.3 to 2.8 GtCO₂ in 2030 (Table 2.4 IPCC, 2018a).

Again, the median value of the range is taken and 1.4 GtCO₂ of the total 2030 emissions for LULUCF is reserved. For 1.5°C a land use sink of 0.1 GtCO₂ is assumed.

The emissions budgets left to be apportioned between states in 2030 are 31.9 GtCO₂e for 1.8°C and 23.4 GtCO₂e for 1.5°C. Adding up the top ends of the fair share ranges of all states would result in 63 GtCO₂e in 2030, which is far above the level consistent with even 1.8°C. Only moving down each state's fair share range by 56% results in the total global emissions level required for 1.8°C; moving down by 72% would lead to the required total global emission level for 1.5°C.

4. Results

The impact of reducing the range of fair share emissions in 2030 is illustrated here by the G20 states (Figure 5) and for all states in the supplementary material.

Developed states that have high historic responsibility, high GDP per capita, etc. end up with a 1.8°C or 1.5°C consistent emissions level in 2030 that is around zero (USA, Japan) or net-negative (e.g. Germany, France, UK). This means that these states have already used their fair share of emissions space and should stop emitting by 2030. If such a level is not reachable with domestic emission reductions, these states will need to correspondingly scale up the support they offer to others to reduce their emissions, based on the principle of cooperation.

Of the G20 states, only India and Indonesia can increase their emissions relative to 2010. The Paris Agreement temperature goal requires global emissions in 2030 to be well below 2010 levels, so only a few selected states can temporarily increase their emissions, as such increases have to be compensated for by other states. Around half the G20 states have moved in the wrong direction over the 2010s, and those decreasing emissions have done so too slowly.

The application of principles of international environmental law generally requires more stringent reductions from developed states than when all equity principles are included. The upper end of the range is reduced by a few percent (grey areas in Figure 5 for Japan and USA) for these states as both grandfathering and least-cost approaches tend to favour them. A few developing states have less stringent reductions, i.e. have the lower end of their range increased (grey areas in Figure 5 for India and China). The exclusion of the category 'equal per capita emissions' (a category that is not the subject of any particular principle of international environmental law) would change the results only marginally as it rarely determines the extreme ends of the range, see supplementary information.

Fair-share ranges determined in this manner provide a guide to national emissions allocations that are fair and adequate and anchored in international environmental law. This article focuses on 2030 emissions because although long-term emissions pathways toward full decarbonization are important, near-term emissions trajectories are vital for meeting the Paris temperature goal. At last count over 120 states had announced mid-century 'net zero' targets, but the scope, credibility, transparency and accountability of these targets is yet to be fully determined. The focus on 2030 emissions is also important because there are significant equity implications – both intra and inter-generational – to focusing on long-term trajectories at the cost of near-term ones.

The results for national emission allocations are sensitive to the input data; any outliers strongly impact a state's range and for bigger states this can also impact the Paris threshold value for other states. The approach adopted here therefore carefully curates the data to minimize the impact of outliers that can be attributed to unsound methodology but includes approaches that reflect perspectives at the ends of the spectrum. Examples include the greenhouse development rights approach, where allocations for developed states are already in the order of –100% in 2030.

In addition, these results do not take land-use emissions into account, either in the final fair-share allocations or in their derivation. This is an important component for states that should be dealt with separately. Among the G20 states, Brazil and Indonesia would have to reduce their emissions at a higher percentage if LULUCF were included.

The global emission levels in 2030 that are compatible with 1.5°C and 1.8°C trajectories rely on substantial emissions removals in the second half of the century. If such levels of emissions removals prove unrealistic (Anderson & Peters, 2016), global emission levels in 2030 would have to be lower than stated here and emission results for every state would need to be at the bottom end of the fair share range provided in Figure 5.

5. Conclusions

This article tests the fairness justifications offered in 168 nationally determined contributions to the 2015 Paris Agreement against the touchstone of principles of international environmental law. It finds that while many NDCs frequently refer to elements and indicators that are backed by principles of international law in *determining* fair shares (sustainable development) (136), special circumstances (122), common but differentiated responsibilities (59) and equity (50), some NDCs justify their contributions on the basis of elements and indicators that are not backed by such principles (indicators such as small share of global emissions (for states that are not LDCs and SIDs) (52), least cost pathways (8), emissions per GDP (24), progression of own effort (55), in line with own targets (26) and peak year (10)).

Using these insights to scrutinize previous analyses of the quantifications of national fair share emissions targets, led to the exclusion of approaches based on cost and grandfathering, both usually favourable to developed states. This in turn led to more stringent reductions for developed and less stringent reductions for developing states.

This narrower range of fair shares can be further *interpreted* using additional principles and normative pillars of the climate change regime. If all states were to choose the highest emission level of their fair share range, which is defined by a different approach for each state, the resulting aggregated global emissions would be as high as 63 GtCO₂e in 2030 leading to catastrophic climate change. The additional principles of harm prevention and precaution, the normative pillars of the climate change regime, as well as the good faith expectation that states intend to align their targets with the long-term temperature goal identified in the Paris Agreement, can be used to further interpret the range. Such an interpretation would require states to discard the upper end of what could potentially be regarded as fair based on selected views of fairness, because if all states chose this option the sum of their contributions would not deliver the agreed temperature goal in the Paris Agreement.

Once the principles of international environmental law have been applied to the *selection* of approaches and the *interpretation* of the range, states with high historic responsibility, high GDP per capita, etc. end up with a Paris compatible emission level in 2030 that is net-negative (e.g. Germany, France, UK, USA, Japan). While there is still a little emissions space or emissions budget available globally, these states have already exceeded their emissions budget under the fair share allocation described here. If their fair share is not reachable with domestic emissions, these states would need to support others to reduce their emissions to make their fair share contribution.

Of the G20 states, only India and Indonesia have a fair share range that is higher in 2030 than their 2010 emissions, and only India has a range higher than today's level. To reach the Paris Agreement temperature goal, global emissions in 2030 would need to be well below 2010 levels, so only a few select states can temporarily increase their emissions, as such increases would need to be compensated by others. These requirements are at odds with recent developments: around half the G20 states have increased emissions over the 2010s, and those decreasing emissions have done much slower than our results suggest they should have. This means that action on climate change needs to be significantly accelerated.

The results of these studies can offer a benchmark for states as they submit their nationally determined contributions under the Paris Agreement, for peer and non-state actor reviews of the 'adequacy' of NDCs, as well as to feed into the periodic global stocktakes. These results can also inform climate litigation in national, regional and even international courts. In the ultimate analysis, states' actions on climate change are not to be assessed solely on the pragmatic basis of what they are willing and able to do. The framework of international environmental law poses principled limits to national determination.

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ORCID

Niklas Höhne  <http://orcid.org/0000-0001-9246-8759>

Gaurav Ganti  <http://orcid.org/0000-0001-6638-4076>

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