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Entry points for assessing ‘fair shares’ in national mitigation contributions

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E-mail: pelz@iiasa.ac.at**Keywords:** fair shares, equity, carbon budgets, nationally determined contributions, foundational principlesSupplementary material for this article is available [online](#)**Abstract**

Fairness considerations have long been central to the international climate change mitigation discourse, generating numerous scientific and philosophical debates. Yet, there remains a pressing need for practical guidance on developing assertions of fairness in national mitigation contributions. The Paris Agreement mandates that subsequent nationally determined contributions (NDCs) submitted under Article 4 represent a progression compared to previous NDCs. Further decisions under the Paris Agreement mandate that NDCs include clear and transparent considerations of fairness, as recalled in the first Global Stocktake. We propose a practical approach to this, comprising a set of ‘entry points’ that represent key stages where decisions are taken in ‘fair share’ quantifications, from interpreting foundational principles to selecting indicators and presenting results. By bridging the gap between scholarly debates and practical application, this work supports the integration of clear and transparent fairness considerations into climate policy commitments. We demonstrate the use of our approach through a case study.

1. Introduction

The origins of contemporary debates over fairness in climate change mitigation can in part be traced back to the Stockholm Declaration, which underscored the need to balance national sovereign environmental policy with the collective obligation to avoid environmental harm beyond one’s borders (Principles 21–24, UN 1972). Principle 23, for example, refers to a differentiation in standards ‘[...] which are valid for the most advanced countries, but which may be inappropriate and of unwarranted social cost for the developing countries’ (Ibid.). This early recognition of shared but differentiated responsibilities was reinforced within the international climate regime during the 44th UN General Assembly in 1989, which noted the disproportionate contributions of ‘developed’ countries to the greenhouse gas (GHG)

emissions driving climate change and recognised the need for international cooperation to support ‘developing’ countries in addressing climate change and its effects (44/207, UN 1989). The subsequent establishment of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 enshrined the principle of ‘common but differentiated responsibilities and respective capabilities’ (CBDR&RC), advocating for the safeguarding of the climate system for benefit of both present and future generations, grounded in the principle of equity (Article 3.1, UNFCCC 1992). CBDR&RC and the broader principle of equity have since been articulated, qualified and expanded on in the Kyoto Protocol (1997) and the Paris Agreement (2015).

The interpretation and application of such principles to inform differentiation has evolved over time (Rajamani *et al* 2021). The political transition to

nationally determined contributions (NDCs) under the Paris Agreement in 2015 is the most recent example, representing an evolution in global climate governance away from the prescriptive and legally binding differentiated emissions targets for developed countries of the Kyoto Protocol to nationally determined targets of the NDCs applicable to all countries (Rajamani and Bodansky 2019, Depledge 2022). The Intergovernmental Panel on Climate Change's (IPCC) Working Group III tracks this evolving conceptualisation through its contributions to the periodic Assessment Reports. Early iterations of these reports discuss several approaches that provide the basis for contemporary fairness considerations, such as equal per capita emissions allocations, proportionality of effort to historical emissions and economic strength, emissions pathways in global or staged convergence, and effort allocation in terms of equal costs, among others (see e.g. chapter 6, table 6.3, page 440, IPCC 2001, and chapter 13, table 13.2, p 770, IPCC 2007). Advances in scientific understanding of the near-linear relationship between cumulative carbon dioxide emissions and specific temperature thresholds spurred efforts towards quantifying 'fair shares' of a finite remaining carbon budget, which we consider here (e.g. Pan and Chen 2010, Jayaraman et al 2012, Rao 2012, Raupach et al 2014, Gignac and Matthews 2015). These advances were captured by the IPCC's fifth assessment report, categorizing approaches and interpretations discussed in the literature into distinct groups that remain in use today (see chapter 4, and chapter 6, table 6.5, p 458, IPCC 2014).

Efforts to bridge the divide between countries, such as those led by the BASIC group (Brazil, South Africa, India and China), have made slow progress despite the wealth of evidence collected on both sides of the science-policy interface (BASICS experts 2011, Pickering et al 2012), reflecting the entrenched nature of the debate (see e.g. Agarwal and Narain 1991, Grubb 1995). These deliberations continue to be central to contemporary political narratives around climate change mitigation (Klinsky et al 2017). In this work, we broadly delineate these debates across two levels, a relatively more abstract level of theory and a relatively more pragmatic level of practice. The former concerns itself with theoretical debates over the interpretation of principles and their function within the international climate regime. The latter concerns itself with the practical application of these concepts in evaluating relative mitigation efforts. We focus our efforts in this paper on the latter.

Motivating this focus are several recent scholarly interventions that have called both for more rigour and for an explicit recognition of the value judgments underpinning analytical decisions in 'fair share' assessments of climate change mitigation effort (Kantha et al 2018, Winkler et al 2018, Dooley et al

2021, Rajamani et al 2021). Winkler et al (2018) and Rajamani et al (2021) specifically discuss these issues in the context of parties' submissions of NDCs under the Paris Agreement, finding largely incomplete or inconsistent descriptions of the analysis underlying assertions of equity and fairness contained therein. We interpret these critiques through our lens of practice, understanding that those conducting 'fair share' assessments, in any context, must be clear about the value judgements that were made and demonstrate a more direct linkage between foundational principles underlying these value judgements and their translation into applied considerations of fairness. Such foundational principles, which we discuss in detail, may draw from international treaties such as the UNFCCC but may also be motivated through national processes and deliberations.

Reinforcing these critiques is the Paris Rulebook itself (Rajamani and Bodansky 2019). While transparent and clear assertions of fairness were not explicitly mandated for the first submissions of NDCs, this changed for subsequent submissions as discussed in the outcomes of the first global stocktake to the Paris Agreement, drafted during the 28th Conference of Parties (COP) (Decision 1/CMA.5, UNFCCC 2024). This decision recalls Article 4.3 of the Paris Agreement which states that subsequent NDCs. '*... will represent a progression beyond the Party's current nationally determined contribution and reflect its highest possible ambition, reflecting its common but differentiated responsibilities and respective capabilities, in the light of different national circumstances*' (Paragraph 167, Ibid.). It then goes further to recall that subsequent NDCs. '*... shall provide the information necessary for clarity, transparency and understanding contained in annex I to decision 4/CMA.1, as applicable to their nationally determined contributions*' (Paragraph 168, Ibid.). Thus, while countries are free to choose their own qualitative or quantitative indicators, the relevant annex to the decision referenced specifically notes the requirement to describe '*... [h]ow the Party considers that its nationally determined contribution is fair and ambitious in the light of its national circumstances*' (annex 1, element 6, Decision 4/CMA.1, UNFCCC 2018).

Considering these requirements and their practical implications, we examine entry points along the path to develop a Party's normative stance on fairness in domestic mitigation efforts. This focusses primarily on quantitative assertions of 'fair shares', recognising that such assessments only cover part⁵ of the full scope of fairness considerations deliberated under the UNFCCC and the Paris Agreement. The article

⁵ We recognise here the adjacent scholarship that has critically engaged with modelled socioeconomic trajectories (Klinsky and Winkler 2018) and qualitative considerations of just transitions and sustainable development pathways more broadly (Foster et al 2024).

Table 1. Entry points for establishing and operationalizing a normative position regarding quantitative ‘fair shares’ in NDCs.

Entry point	Description	Self-reflection
Foundational principle	The foundational principles and their interpretation.	Have the principles and their sources been clearly defined? Has the consistency (or lack thereof) across principles been communicated?
Allocation quantity	The object to be allocated, whether fixed over some period or considered annually.	Has the allocation quantity been reported? Have all parameters necessary to replicate this quantity with publicly available data been provided? Has its alignment with the principles considered been clearly explained?
Allocation approach	The approach used for distributing or allocating the quantity.	Have the allocation approaches been defined? Have clear mathematical representations enabling replication been provided? Has their alignment with the principles considered been clearly explained?
Indicators	The measurable data used to operationalise the allocation approach.	Have all indicators and their publicly available sources been provided? Has their alignment with the principles considered been clearly explained?
Implications for all others	The consequences of the allocation process for all other parties.	Has the remaining quantity available to all other parties been clearly communicated?

begins by drawing illustrative examples from current NDCs to motivate consideration of the entry points we identify. We then demonstrate how to practically consider these through an illustrative case study. We conclude by calling for a clear definition of foundational principles in any practical assertion of fairness, and in the specific case of ‘fair share’ quantification, following this with a specification of the allocation quantity, definition of the allocation approach and presentation of indicators selected to operationalise this. We argue that this approach provides a level of clarity and transparency both in line with the mandate of the Paris Agreement and in support of necessary global stocktaking and assessment.

2. Assessing entry points for assertions of fairness in contemporary NDCs

We begin with describing entry points in the practice of quantifying ‘fair shares’ underlying assertions of fairness in NDCs to the Paris Agreement. These entry points represent decisions that may be made at different times by different groups of people during the formulation of a fairness assertion. Making or assessing these decisions is predicated on a clear definition of purpose, which in our case is assessing whether an NDC transparently and clearly presents an assertion of fairness. An example of another distinct purpose may be the assessment of compliance by legal scholars and in judicial proceedings relating to the adequacy of national climate targets (Van Berkel 2020), requiring a clear definition of

this purpose prior to consideration of these entry points.

These entry points bridge theoretical and normative critiques (see e.g. Dooley *et al* 2021, Rajamani *et al* 2021) to provide simple heuristics guiding the development or assessment of a party’s assertion of fairness. We describe these using selected examples from contemporary NDCs that serve as illustrations rather than demonstrations of issue prevalence (for the latter, see Winkler *et al* 2018). Each example we use reflects as far as possible the full fairness assertion text identified in the respective NDC, which we do not trace back to a specific party since that is not the purpose of this exercise. Table 1 summarises the entry points we discuss, listing a series of questions for self-reflection that aid in the clear and transparent communication of decisions taken in practice during the quantification of a ‘fair share’. Alongside the entry points we discuss here, we also recognise the importance of communicating implications of a specific assertion by one party for all others (Meinshausen *et al* 2015, Dooley *et al* 2021, Lecocq and Winkler 2024). Omission of this final element leaves the fairness assertion incomplete, as it does not recognise how the party’s assertion affects the available quantity for all others, nor what this would mean for the collective feasibility to achieve the global climate targets without explicit compensatory measures.

2.1. Foundational principles

The first entry point in an assertion of fairness involves identifying relevant foundational principles.

These principles establish what is considered ‘fair’ and form the basis of any subsequent assertion. A common challenge here lies in the indeterminate nature of principles established through international treaties, which often allow for varied interpretations that may change over time, either by design or as a compromise to achieve consensus (Geden 2016, Rajamani 2016). To address this, principles may be drawn upon from other relevant sources to clarify a given interpretation. For example, principles formalised in international environmental law have been applied to inform the interpretation and operationalisation of ‘fair shares’ of mitigation effort (Rajamani *et al* 2021). Philosophical and climate justice literature also provides guidance in defining and interpreting foundational principles (Shue 2014, Meyer 2017, Caney 2021). National constitutions and legislation may also be relevant in contextualising the domestic interpretation of principles invoked in international agreements (Kingston 2020).

Principles can be interpreted either in isolation or in combination, reflecting different theories of justice. If considered in combination, it is important to ensure that the constituent principles are internally consistent. Dooley *et al* (2021) discuss such contradictions in the equity literature, illustrating challenges that arise when principles such

as guaranteeing a minimum standard of living for vulnerable populations conflict with principles like grandfathering, which protect the existing advantages of the wealthy. Such contradictions can deny vulnerable groups the resources needed to meet their basic needs (Dooley *et al* 2021). Rajamani *et al* (2021) extend this critique from a legal perspective, emphasizing the importance of not only maintaining consistency between principles but also aligning them with principles of international law. They highlight issues in contemporary NDCs where the chosen indicators, and their justifications (foundational principles) or lack thereof, fail to meet these criteria. Examples include assertions based on ‘small shares of global emissions’ for countries that are not LDCs or SIDs, reliance on least-cost pathways, or emissions per gross domestic product (GDP), as well as considerations of peak year and progression of effort (Rajamani *et al* 2021). In all cases, clearly communicating the source of a principle is crucial to avoid confusion. For example, the qualifier ‘...in light of different national circumstances’ added to the CBDR&RC principle in the Paris Agreement could be interpreted as a substantive shift from its original meaning under Article 3.1 of the Convention as referenced by the Kyoto Protocol (Rajamani 2016).

	<i>‘The [party] NDC exceeds a straight-line path to achieve net-zero emissions, economy-wide, by no later than 2050.’</i>	<i>Example 1.1</i>
<i>Example Set 1</i>	<i>‘This NDC reflects the [party’s] efforts in the context of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances. ... As a developing country with limited sources economy and historically low GHG emission contribution, the [party] considers its 2030 ambition as fair, given that the sum of the contributions leads to a significant deviation from a business-as-usual scenario emission.’</i>	<i>Example 1.2</i>
	<i>‘[assessment is conducted using independent tools that consider] ... equity principles [the party] values and prioritises—taking into account responsibility and capability, as well as the right to promote sustainable development and the need to prioritise development for those living in poverty.’</i>	<i>Example 1.3</i>

We now turn to a set of examples to illustrate the consideration of this entry point in contemporary NDCs (Example Set 1). In Example 1.1, the assertion of fairness rests on the pursuit of ambition in line with own targets, i.e. exceeding the pace set by a self-determined benchmark with no reference to other parties. The omission of a principled basis defining the objective of this fairness assertion makes it impossible to infer how this relates to principles discussed in the Paris Agreement and the UNFCCC. In Example 1.2, the principle of CBDR&RC is referenced in a preamble, followed by an assertion of fairness in the subsequent text. While the source of the referenced principle is not provided, one may infer this refers to the text in Article 4.3 of the Paris Agreement, which includes the caveat regarding

national circumstances. Issues arise here due to the subsequent qualification in the fairness assertion (effort reflecting a deviation from business-as-usual). This is arguably in contradiction with CBDR&RC as it no longer reflects an assessment in relation to other parties (see the importance of ‘relative fair shares’ in Winkler *et al* 2018), but rather an assessment in relation to one’s own ambition. In Example 1.3, foundational principles are transparently communicated and sourced (referencing independent assessment tools not included in this excerpt) allowing them to be critically evaluated. These examples illustrate how conceptual ambiguities in foundational principles, whether omitted or invoked but not applied in practice, can lead to a lack of clarity and transparency in fairness assertions at this foundational entry point.

2.2. Allocation quantity

The allocation quantity defines what is to be distributed and is related in a robust manner to meeting global climate targets. This can be a finite carbon budget underlying a global mitigation pathway, the global mitigation pathway itself or another measurable finite quantity. In all cases, this requires several value judgments such as choosing the intended climate target, the probability of meeting the target, the estimated contributions of non-CO₂ emissions, emissions and sinks from land-use and land-use change and forestry, or the historical period considered, among other considerations (Robiou du Pont *et al* 2017, Rogelj *et al* 2019, Matthews *et al* 2020). Here the allocation quantity may, for example, also consider: cases where benefits are folded into the consideration of efforts (Rao 2022), quantities beyond carbon budgets and emissions pathways such as scenario-derived mitigation investment needs (Pachauri *et al* 2022) or carbon dioxide removal obligations (Fyson *et al* 2020).

The allocation quantity is fundamental to quantitative assessments of relative fairness underlying an assertion of a quantitative ‘fair share’ (Winkler *et al*

2018). A lack of clarity and transparency may arise here when decisions made in its definition are not clearly communicated, or when it is omitted altogether. For instance, translating the long-term temperature goal of the Paris Agreement to keep global warming well-below 2 °C and pursue efforts to limit it to 1.5 °C relative to preindustrial levels to a remaining carbon budget or an emissions pathway is a value-laden exercise that may result in substantively different aggregates (CONSTRAIN 2019), aside from associated scientific uncertainties (Lamboll *et al* 2023). Fairness assertions that do not clearly define the choices informing the allocation quantity do not provide sufficient clarity. This is an intuitive but nevertheless important issue, given that NDCs typically discuss only a single party’s future emission pathway or a single party’s ‘fair share’ (if at all). In the following examples drawn from contemporary NDCs (Example Set 2), we explore cases where a lack of clarity and transparency in the allocation quantity leads to a relative assessment of fairness that is uninformative, irrespective of whether decisions at other entry points are clearly.

Example Set 2	‘[The party’s] updated NDC is a progression on our previous 2030 target and a significant increase in ambition, committing [the party] to reduce greenhouse gas emissions by 43% below 2005 levels by 2030—half as much again as the previous target of 26%–28%—and achieve net zero emissions by 2050.’	Example 2.1
	‘[The party] would be contributing with a reduction in the order of magnitude of what the IPCC says countries must achieve to keep the 1.5 °C target on track.’	Example 2.2
	‘... NDC is consistent with global mitigation efforts to limit global warming to well-below 2 °C and [the party] considers it to be a fair contribution ...’	Example 2.3
	‘To not exceed 1.5 degree temperature [sic] by 2050, the budget set by the Intergovernmental Panel on Climate Change (IPCC) is 650 GtCO ₂ .’	Example 2.4

In Example 2.1, the allocation quantity (in terms of a reference pathway) is not provided, such that assertions of fairness can only be discussed in terms of a progression of earlier effort. While targets are given, they have no substantive link to global climate goals. It is therefore impossible to relate the ambition shown here with that of other parties and thus assertions of relative fairness are effectively mute. In Examples 2.2 and 2.3, the allocation quantities are discussed ambiguously, such that the likelihood of achieving the temperature target and the resulting pathway or budget corresponding to this cannot be reliably inferred. This is critical as remaining carbon budget quantities and associated assumed emissions pathways shift substantially with the likelihood of achieving a temperature target (see e.g. Rogelj *et al* 2017). In Example 2.4, the allocation quantity reflects a remaining carbon budget (from

the year 2010, discussed in the full text) and draws on the available science at the time given a specified temperature increase goal. While the corresponding likelihood considered is not clearly communicated, it can be inferred from the cited underlying report to which the NDC refers using the provided absolute budget, as can the global emissions pathway implied by this budget. These examples show that the lack of a clear and transparent allocation quantity not only hinders the comparative assessment of mitigation effort reported in submitted NDCs but also obscures the pathway towards achieving global climate targets. A well-defined allocation quantity, supported by the best available science as required under the Paris Agreement, is crucial to enable assessments of how assertions of fairness in NDCs relate to collective climate goals.

2.3. Allocation approach

The allocation approach specifies how the quantity (for example, the remaining carbon budget, or a desired future emissions pathway) is allocated. Several approaches and their derivatives exist in the literature (see e.g. chapter 6, table 6.5, p. 458, IPCC 2014), and new allocation approaches are likely to arise, for example through the need to address quantities informing loss and damage, adaptation and differentiated climate vulnerability more broadly (Chalifour 2021). Allocation approaches distribute a quantity across some set of parties, typically but not necessarily at the state level, and may or may not

consider sub-national differentiation. They are usually qualified with a timeframe over which the quantity is to be allocated, clearly stipulating the period of consideration. Broad conceptualisations of allocation approaches may lend themselves to multiple possible interpretations. In the following examples from contemporary NDCs (Example Set 3), we show that this may result in substantively different quantifications of ‘fair shares’ such that a comparison of the resulting allocations to a party’s intended emissions pathway is likely uninformative.

	<i>‘The contribution of each individual actor to temperature increases should take into account differences in terms of starting points, population, approaches, economic structures, natural resources, the need to maintain sustainable economic growth, available technologies and other individual circumstances.’</i>	Example 3.1
Example Set 3	<i>‘It is considered fair, given that [party A’s] contribution to global emissions is 1.3% of the global total, with per capita emissions of 3.7 tons, which is below the average global emission of 5 tons per capita, that is, 4.4 times less than that of our main trading partner, [party B], with 16.5 tons per capita.’</i>	Example 3.2
	<i>‘[Using an index to determine allocations of a carbon budget that reflects ...] Historical responsibility. Includes responsibility for the cumulative emissions since the pre-industrial era (1750–2010). ... [followed by other factors and subsequently by a mathematical representation of the index].’</i>	Example 3.3

In Example 3.1, the allocation approach includes several possible facets of differentiation that require value judgements in their operationalisation. The text does not expand on how to apply this to assess temperature increase responsibility, nor does it expand on how this is to be related to a ‘fair’ future emissions pathway for the party in question. As such, it is impossible to infer which of the possible operationalisations have informed the assertions of fairness made. In Example 3.2, while the allocation approach references two facets of differentiation—namely ‘small share’ of historical responsibility and per-capita emissions relative to the global average (and one reference party), it does not define how these are used to define a forward looking relative ‘fair share’. The ‘small share’ approach was the most commonly reported equity consideration in INDCs assessed by Winkler *et al* (2018), who discuss issues of a lack of consistency in its use. In this case, its applicability to assess other party’s relative mitigation efforts is unclear, as the assertion rests on a binary ‘below the average’ per capita historical emissions status, suggesting no differentiation between parties in this group. In Example 3.3, the allocation approach is clearly and transparently described including the provision of a mathematical representation (in the subsequent text, not shown in this excerpt) that can be critically evaluated, alongside clear statements regarding the period of consideration. This fosters replication by other parties

to increase mutual understanding. These examples highlight the importance of a clearly and completely defined allocation approach in assessments of fairness. This is essential to enable parties to understand and evaluate the basis of each other’s contributions, facilitating the assessment of NDCs in relation to each other and to global climate goals.

2.4. Indicators

Indicators represent the data used to operationalise an allocation approach. Indicators may be characteristics of regions, countries, or populations, and require choices about how they are reflected. Selecting appropriate indicators necessitates navigating debates within the literature, such as the selection of gases to consider, the accounting approach for distinct gases, the time period over which indicators are considered and the role and allocation of specific sectoral emissions sources and sinks (Steininger *et al* 2014, Dhakal *et al* 2022, Meinshausen and Nicholls 2022, Matthews *et al* 2023). The application of indicators may also require their transformation to a suitable (inverse) range for allocation, requiring another set of value judgements.

A lack of clarity at this initial stage can arise when ambiguously defined assertions of fairness allow for multiple plausible indicators, leading to substantively different allocations. Given the widespread omission of specific indicators in current NDCs, we focus

on the common example of ‘capability’ to illustrate this issue. Many fairness assertions in contemporary NDCs reference relative capabilities without clearly defining the indicators used as a proxy for this concept. The choice of indicator can significantly affect allocations; for example, using per capita GDP as a proxy for capability without specifying whether it is measured by purchasing power parity or market exchange rates (MER) can result in quite different outcomes for specific parties. This issue is compounded when the selected indicators are arbitrarily transformed, such as being mapped onto an inverse range, without a clear explanation of the function used or the rationale behind the choice. Such opaque decisions can lead to allocations that deviate significantly from the original intent of representing the differences between parties as measured by the selected indicator. These hidden choices can undermine the faithful application of the allocation approach. At a minimum, the indicators and methodological choices made at this entry point must be explicitly stated to allow for replication and critical assessment. Given the limited evidence that such considerations have been addressed in current NDCs, improving clarity and transparency at this entry point represents a critical area for improvement in the next round of submissions.

3. Case study illustrating entry points in ‘fair share’ quantifications

We now demonstrate the consideration of each entry point using a case study of the European Union (EU27), a geopolitical region comprised of 27 member countries. This case study region was selected in light of a contemporaneous science-policy process in the region that has considered the implications of relative ‘fair shares’ in informing climate targets (see European Scientific Advisory Board on Climate Change 2023). The intention with this case study is solely to demonstrate the process of transparently considering each entry point in an internally consistent manner (see Supplementary Materials) and to illustrate the presentation of this, rather than specifically arguing whether these are the best or only possible decisions that may be made, which we leave for future work to deliberate. Table 2 summarises the entry points underlying our illustrative fairness assertion for the region, as well as the resulting remaining allocations. For the sake of conciseness, we provide only a bare minimum synthesis of the decisions taken in the summary table here. A detailed discussion of each entry point as well as the implications of these allocations for all other parties can be found in the Supplementary Materials.

The outcomes show remaining allocations in our case study that are negative as of 2023. These negative allocations provide an opportunity to briefly discuss the versatility of the approach to inform

domestic ambition reflected in an NDC while recognising responsibility for past inaction under a rapidly approaching global overshoot trajectory. Importantly, the approach as applied here does not necessarily lock a party into prescriptive choices about precisely how or when to address ‘fair share’ breaches, or indeed how to consume a remaining budget were this to exist. Rather, informed by such ‘fair share’ considerations, a party can define and position their highest possible domestic ambition informed by the best available science in line with the Paris Agreement (Rajamani 2016, 2024, Mayer 2024, Schönfeld and Rogelj 2024) and explicitly communicate any existing or expected ‘fair share’ breaches that need to be addressed through strategic negative emissions targets and by supporting global mitigation efforts, while recognising the global harms associated with the duration and magnitude of their respective allocation overshoot. In reflecting on this it is important to recall here that the approach intentionally allows for flexibility as it may be required to answer different questions that require different allocation quantities.

The consideration of entry points in assertions of fairness as shown here serves thus as one component of domestic deliberations, alongside weighing trade-offs, such as the costs and desirability of ambition versus delay, in developing actionable NDCs. While the decisions we take in this case study are not definitive interpretations of underlying principles, they demonstrate the practical value of communicating decisions taken at each of the identified entry points, inviting welcome critique. The level of clarity and transparency achieved is a natural result of the necessary assessment and self-reflection at each stage of the assertion. Following such an assertion, it would be possible for example to conduct sensitivity assessments of the implications of alternative choices to those made at each entry point as desired. The use of these entry points may also guide discourse across groups and over time, as the assertion is developed and revised in consultation with all relevant stakeholders.

Importantly, this case study (in its entirety, including the elements discussed in our Supplementary Materials) is intended to trigger critical reflection amongst readers. We argue that this response ought to be welcomed and demonstrates the value of a focus on the selection and interpretation of foundational principles and their faithful representation in quantitative assessments, rather than suffering under the weight of all possible allocation approaches available in the literature. Clearly communicated decisions at each entry point allow the reader to examine whether they agree with the assertions made and their alignment with the foundational principles we posit to have interpreted. It is this critical examination that separates such an approach from one that starts with all possible allocations

Table 2. Approach application to allocate a remaining carbon budget for the European Union as of the year 2023. C1 indicates scenarios classified in the scenarios database to the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) as those that limit warming to 1.5 °C with no or limited overshoot. UN indicates data from the United Nations World Population Prospects. WDI indicates data from the World Bank's World Development Indicators. GCP indicates data from the Global Carbon Project. SSP2 indicates Shared Socioeconomic Pathway Two (middle of the road) projections from the International Institute for Applied. Systems Analysis (IIASA).

Principle	Allocation quantity	Allocation approach	Indicators	Allocation remaining
<u>EU Climate Law:</u> Polluter Pays, Do no harm, Precaution	A remaining carbon budget consistent with a target limiting warming to 1.5 °C with a 50% likelihood, estimated at 247 GtCO ₂ from 2023 onward (Lamboll <i>et al</i> 2023).	ECPC1990,	Population 1990–2019 (UN)	1990: 77.5 GtCO ₂ -FFI
		An allocation in the year 1990, assuming: equal cumulative per capita allocation 1990–2050.	CO ₂ -FFI 1990–2022 (GCP) Population 2020–2050 (SSP2)	2023: -35.7 GtCO ₂ -FFI
<u>Paris Agreement:</u> CBDR-RC	From this aggregate we subtract projected median international bunker emissions from 2020 under C1 scenarios from IPCC AR6 (46 GtCO ₂). To define a total remaining carbon budget from 1990 we add to this aggregate CO ₂ -FFI emissions from 1990 to 2019 inclusive (852 GtCO ₂ -FFI).	CPC1990adjCAP,	Population 1990–2019 (UN)	1990: 27.1 GtCO ₂ -FFI
		An allocation in the year 1990, assuming: equal cumulative per capita allocation 1990–2050, scaled in inverse proportion to cumulative per capita 1990–2019 GDP (latest consistent period).	GDP MER 1990–2019 (WDI) CO ₂ -FFI 1990–2022 (GCP) Population 2020–2050 (SSP2)	2023: -86.1 GtCO ₂ -FFI

and works backward to select those which are most favourable.

4. Conclusion

In this article we engage with the practice of ‘fair share’ quantification informing assertions of fairness in national mitigation contributions. Our work translates theoretical and normative critiques in the literature to practice, identifying key entry points in developing or assessing an assertion of fairness. We illustrate and motivate these entry points through examples from contemporary NDCs. In anticipation of the upcoming revision cycle and the reiterated call for enhanced ambition in the recent decision under the UNFCCC (2024), this work offers a pragmatic approach designed to assist policymakers and analysts. Its application can guide ongoing NDC revision and assessment processes, aligning efforts with evolving international expectations.

The central theme in this work is the importance of transparently communicating foundational principles considered, their interpretation and their practical application in quantitative assessments of fairness in national mitigation contributions. This

transparency can enrich cross-party dialogue regarding ambition and perceived fairness that may be lost in translation. We advocate for a principled self-assessment and reflection by individual parties, encouraging them to consider the broader implications of their positions.

Our case study illustrates a possible consideration of identified entry points to investigate ‘fair shares’ of a remaining 1.5 °C carbon budget for the EU, in line with selected principles of the European Climate Law and the Paris Agreement. This exercise showcases the value of clear and transparent communication of the decisions made at each entry point, inviting and enabling critical assessment and replication. The resulting negative remaining allocations underscore its versatility under threat of overshoot. By upholding a fixed climate target and following principles that are considered foundational, parties can motivate the pursuit of highest possible domestic ambition while transparently communicating and addressing any resulting breach of ‘fair shares’, through negative emissions targets and international cooperation, in line with global climate goals (Pelz *et al* 2024, Schönfeld and Rogelj 2024). The importance of minimising overshoot duration and magnitude

is discussed in recent work (Pfleiderer *et al* 2024, Schleussner *et al* 2024) and should be drawn upon in future efforts that deliberate necessary actions and their timelines in cases where a party's principled 'fair share' is deemed to have been exhausted.

In closing, we note that fairness considerations in climate change mitigation are dynamic, requiring periodic updates to reflect bidirectional domestic and international information flows and reactions to collective ambition enhancement (Holz *et al* 2023) as well as the latest scientific insights on the required efforts (see e.g. Lamboll *et al* 2023, Zickfeld *et al* 2023, Rogelj and Lamboll 2024). The entry points and approach we outline ensure that quantitative assessments supporting fairness assertions are both replicable and adaptable to evolving circumstances. Recognizing these entry points is essential for advancing the discourse around equity in global climate action. By addressing recent theoretical and normative critiques, our approach fosters greater transparency in fairness assessments. Achieving this in turn requires concerted effort by parties to clarify their positions and enhance collective understanding, ultimately supporting the ambitious goals of the Paris Agreement and the broader UNFCCC process.

Data availability statement

No new data were created or analysed in this study.

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Conflict of interest

No potential competing interest were reported by the authors.

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