



Defining just transition

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ABSTRACT

Climate change has sparked a vivid discussion on its socio-economic risks, capturing the attention of academic circles and policymakers. While it is widely argued that a low-carbon transition should be socially just, the precise criteria that policies must adhere to, in order to be universally accepted as 'just', remain insufficiently defined. To fill this gap, we draw on relevant theories of distributive justice where equal responsibility should lead to equal outcomes. According to our definition, just transition policies should minimise relative costs for the most vulnerable groups. Furthermore, uneven responsibility for causing damages should be also taken into account by discounting the importance of relative costs of groups with high responsibility.

1. Introduction

Moving to a low-carbon economy is a costly process, which requires a variety of policies on local, national, regional and global levels (Foxon, 2011; Green and Gambhir, 2020; Dechezleprêtre et al., 2022; Semieniuk et al., 2023; Weitzel et al., 2023). The costs of each proposed policy can be unequally distributed across sectors of an economy, with non-green sectors having to pay higher costs (Balta-Ozkan et al., 2015; Diffenbaugh and Burke, 2019; Vona, 2023). Since the late 1980's, labour unions have asked for the protection of employees in these sectors, arguing in international meetings that a low-carbon transition should also be socially just. This type of approach regarding a *just transition*, highlighting aspects of justice that should be taken into account in green transition policies, has been getting increasing traction over the last 30 years.

The concept of a just transition has its roots in the union movement

in the 1980's and first appeared in official international policy documents in 2010 at Conference of the Parties (COP) in Cancun: '[...] a just transition of the workforce that creates decent work and quality jobs' (UNFCCC, 2010). Aiming to provide a more concrete description of what this concept means, the International Labor Office of the UN put forward a 'just transition framework' (ILO, 2015) acknowledging the issue of transition-related inequalities and proposing ways to deal with these. The 2015 Paris Agreement (COP21) identifies the 'just transition of the workforce and the creation of decent work and quality jobs' (UNFCCC, 2015) as an essential goal, while similar comments have been made in other COPs.¹ Moreover, the European Green Deal features a Just Transition Mechanism, and the European Commission has proposed the creation of a Climate Social Fund; systemic equality and a just transition were among the arguments for a Green New Deal in the US as well (see Boyle et al., 2021; McCauley et al., 2023).

Parallel to the policy-making arena, the issue of a just transition has

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¹ For example, see the 'Solidarity and Just Transition' document in COP24 and the 'Just transition declaration' of COP26.

been a topic of interest within different academic literatures across social sciences and humanities often linked to issues related to sustainability.² Various works discuss what the general characteristics of justice should be (for example see Newell and Mulvaney, 2013; McCauley and Heffron, 2018; Fanghella et al., 2023; Zimm et al., 2024, among others); however, an explicit definition of a just transition does not exist (Vollebergh, 2023). Hence, it is impossible to concretely judge which environmental policies related to a low-carbon transition should be considered as just. This paper aims to fill this gap by formally developing a criterion which can define which green policies should be labelled as just. In this way, our paper provides a framework that can be used both in relevant research and in analysing policies.

Our definition incorporates distributive, procedural and restorative aspects of justice which have been argued to be desirable components of a just transition framework (McCauley and Heffron, 2018; Robinson and Carlson, 2021; Cañizares et al., 2024). We consider our approach to be broadly rooted in ‘luck egalitarianism’³ literature which emphasises that unequal circumstances should not have a negative impact on peoples’ lives. More specifically, within this literature our definition shares some similarities with Roemer’s (1998) theory of Equality of Opportunity (EOp) the focus of which is unequal circumstances across social groups. However, due to the unique challenges associated with the low-carbon transition, it is necessary to move beyond existing studies in order to effectively address the unequal impacts of policies and the varied responsibilities of stakeholders. Specifically concerning the EOp framework, our approach diverges in two key aspects, which prevent us from categorising it as an EOp definition. First, while according to EOp, the population is divided into groups (types) ex-ante based on characteristics for which people should not be held responsible, in our definition, types are defined based on the relative net costs of policies.⁴ Second, in order to take into account the issue of possible differential responsibility across types and through this include restorative justice considerations, we apply to the relative costs of each type a weight that is inverse to the type’s relative responsibility for environmental degradation.

The next section provides an overview of the relevant theories of distributive justice upon which our approach is based. Section 3 presents our just transition framework. Section 4 discusses how our definition encompasses key desired aspects of justice (distributive, procedural and restorative) and highlights the differences between other approaches. The last section provides a concluding discussion and directions for future research on the topic.

2. Distributive justice foundations

The relationship between luck, responsibility and justice has been a question of interest and source of debate between economists and philosophers working on distributive justice for over 50 years. A key question of this debate has been what is the appropriate *equalisandum* defining justice. The answer to this question has been mostly defined by the appropriate balance between responsibility regarding people’s actions on the one hand and brute luck with respect to the situations people find themselves in, on the other.⁵

² Through the issue of sustainability, it is possible to also draw links with the de-growth literature (see Muraca, 2012; Cosme et al., 2017; Hickel et al., 2022, among others).

³ The term ‘luck egalitarianism’ was coined by Anderson (1999) and captures the literature initiated by Rawls’ (1971) *Theory of Justice* and evolved through a number of contributions including Dworkin (1981a, 1981b), Arneson (1989, 1990) and Cohen (1989, 1993) among others.

⁴ The consideration of relative net costs arises from recognizing that the transition will involve both costs and benefits. Throughout this discussion, we will refer to the relative costs, meaning the relative “net” costs.

⁵ For a detailed discussion regarding luck egalitarianism see Knight (2009), Lippert-Rasmussen (2016) and Arneson (2018) among others.

Arguably the most important influence in theories of fairness regarding the importance of luck (or lack of it) has been the work of Rawls (1971) who puts forward two principles that define justice. According to the first principle (the ‘liberty principle’), a just society should first provide all its members with a maximum level of basic civil liberties. The second principle of Justice (the ‘equality principle’) is divided into two further principles: The fair Equality of Opportunity Principle, according to which all members of the society should have effectively the same opportunities for different positions and the Difference Principle, which argues that the institutions should act such that the worst-off individuals’ index of primary social goods are maximised. Note that as the focus here is the primary goods of the worst-off individuals this defines two breaks from Utilitarian or Weighted Utilitarian welfarist traditions where the focus also takes into account the population size.⁶

Rawls’ theory emphasises that several characteristics of individuals are due to circumstances beyond their control. Hence inequalities related to these circumstances are not morally justifiable. This approach gave birth to a debate between philosophers and economists including Sen (1980), Dworkin (1981a, 1981b), Arneson (1989, 1990), Cohen (1989, 1993) and Roemer (1996, 1998) focused on where the line of responsibility should be drawn. Dworkin makes the issue of responsibility a focal point of the debate following his seminal contributions (Dworkin, 1981a, 1981b). More specifically he argues against equalisation of welfare as this could for example imply higher resources for people with expensive tastes. He instead argues for equalisation of resources which can then lead to different levels of welfare.

A major critique to Dworkin’s theory of justice has been the fact that individual preferences depend (at least to some important extent) on factors which are beyond one’s control even if one identifies with these preferences (Roemer, 1996). This critique aims to relocate Dworkin’s ‘cut’ in order to make a more clear division with respect to what should be considered one’s responsibility and what not, by explicitly taking into account the relation between the preferences and the endowments, part of which are beyond one’s control. Related debates with key contributions by Arneson (1989) and Cohen (1989) among others focused on allocating the cut between responsibility and circumstances are to a great extent about providing a definition of what constitutes fair EOp.

In the 1990’s an important part of this debate took place within Economics with leading contributions of Van de Gaer (1993); Fleurbaey (1995); Bossert (1995, 1996) and Roemer (1998), among others. By explicitly looking at welfare (or well-being) this literature steps away from Rawls. While the various approaches to EOp agree on the importance of distinguishing between circumstances beyond one’s control (for example, date of birth or parental socioeconomic background) and effort that should be rewarded, there are disagreements regarding the extent to which circumstances influence preferences and effort. Following this distinction, individuals can be divided into types according to their circumstances. In particular, individuals will differ within each type with respect to several characteristics, such as effort for which they should be held responsible. In this way, inequalities across types are unjust, while inequalities within types can be justified.

According to Roemer (1998), policies aimed to achieve EOp should maximise the average person in the types with the worst of circumstances, while, for example, Van de Gaer (1993) proposes maximising the average of the worst-off across types. While the details regarding the differences between the various models are important for normative economics, their discussion goes beyond the scope of this paper (see Roemer and Trannoy, 2016, for an overview and a more detailed discussion). Both Van de Gaer (1993) and Roemer (1998) stress that EOp policies should aim to maximise different worst-off individuals and, in this way, ‘correct’ for unfair inequalities through slightly different

⁶ For a recent discussion on Utilitarianism and distributive justice see Galanis and Veneziani (2022).

'maximin' procedures.⁷ This part of the distributive justice literature which emphasises that equal responsibility should lead to equal outcomes is very relevant for our definition of a just transition for two key reasons. First in the EOp literature the focus has moved (to a great extent) from individuals to (social) groups and this is closely aligned with the just transition concerns since the early 1980s. Second research within this philosophical and economic tradition has been extended to an empirical direction by measuring the difference in outcomes across types (for example see Roemer, 2002; Bourguignon et al., 2007; Ferreira and Gignoux, 2011), which is very relevant from a policy perspective. However, as we discuss in the next two sections, the specificities around a low carbon transition, require us to go beyond the EOp approach.

3. Definition of a just transition

We aim to provide a definition of just transition general enough to be able to be applied to different set ups. Our starting point is the fact that a low-carbon transition is a costly process, and each policy may lead to different allocations of costs within a population. The primary costs associated with the low-carbon transition include job losses, capital investments, stranded assets and economic disruptions. Moreover, the impact of the transition can vary significantly across regions. Developing countries may face higher relative costs but can also gain disproportionately large benefits from health improvements and climate resilience (Hallegatte et al., 2016). Vulnerable populations, such as low-income communities and workers in fossil fuel industries, need targeted support to manage the transition. This can include retraining programs, social safety nets, and inclusive policy design (Jenkins et al., 2018). However, it is important to recognize that there are also substantial benefits associated with this transition. Energy-intensive industries may bear higher costs, while sectors like renewable energy and technology may benefit from new opportunities and growth (Newell and Paterson, 2010). In the long run, the shift to a low-carbon economy can lead to net benefits, including higher productivity (Acemoglu et al., 2012; Su et al., 2023), reduced local pollution (Bollen et al., 2009; West et al., 2013), and improved public health outcomes (Markandya et al., 2009; Sovacool et al., 2020). For the purpose of our paper, we focus on net costs in the short to medium run.

Even though the broad ethical principle that equal responsibility should lead to equal outcomes is relevant for our analysis, our approach requires a change of focus compared to EOp. To get an equivalent formulation of policy characterisation as EOp's maximin of outcomes, we need to focus on relative net costs as these are at least to some extent interpersonally comparable. This then implies that just transition policies should be such that some relative net costs are minimised. But which are the costs that should be minimised? This brings us to the need of defining types which leads to another difference compared to EOp. Our starting point in the baseline definition of just transition is equal responsibility. Assuming equal responsibility within a population would be in theory better to be able to choose policies which equalise relative costs across the population. However, this is impossible from a policy perspective, thus aiming for equalisation of costs across types is a reasonable approximation.

Note that while focusing on relative net costs has an impact on the partition of the population in types; the partition will be defined to a great extent by the specific policy that is implemented. To show this more clearly, let us use an example inspired from the just transition arguments of the union movement. The East Midlands region in England has a history of manufacturing and industrial activity including steel production and automotive manufacturing, hence the shift towards cleaner energy sources affects these industries. In this case a first division of types based on relative costs could be between workers in East

Midlands affected factories, firm owners of these industries and the rest of the East Midlands population. Subsequently, different policies can not only affect the levels of relative costs between these three types but also can lead to further types. For example, new regional taxes could be levied to fund a programme supporting workers that have lost their jobs. The way that these taxes are distributed across the population then plausibly creates new types. As this example shows, in our context, it is not appropriate to define types *ex-ante* based on circumstances as is the case with the EOp approach, but *ex-post* according to the distribution of relative costs which themselves depend on available policies. This constitutes a key difference with Roemer's EOp.

Up until now, our argument has focused on a baseline case where equal responsibility should lead to the same relative costs. Assuming different feasible green transition policies, the just one should be the one which minimises the highest relative costs of a type, where types are defined to some extent by the available feasible policies.⁸ Note that given that types depend on specific policies, our approach provides a criterion to choose from existing policies instead of explicitly designing one. In order to make this clearer, consider the following example: a government who is in favour of a just transition faces a choice between two possible feasible policies, A and B, each of which are able to reach a given environmental target. If policy A is adopted, the primary division of costs is between regions South (S) and North (N) and the costs in terms of loss of regional incomes are 10 % and 5 % respectively. If policy B is adopted then the division of costs occurs between high income (H) and low income (L) earners, with the relative costs being 3 % for the former and 12 % for the latter. In this setup, the just transition policy would be A, as the highest costs under A (10 %) are lower than the highest costs under B (12 %), irrespective of whether the loss of income concerns a region or an income group.

Having established the baseline version of the criterion for selecting the just transition policy, we can now relax the equal responsibility assumption, as unequal responsibility towards environmental damages is an important normative issue when considering just transition.⁹ The way for introducing responsibility in our definition of justice should be such that if one type has considerably more responsibility related to climate damages (i.e. higher per capita emissions), then this type should also bear a higher level of costs for the transition. This seems evident in cases where the type with the lowest contribution to damages equally has the highest relative costs under all feasible policies. In situations like this, applying the previous minimax formulation regarding relative costs is reasonable. However, this is not the case when the type with the highest responsibility is the one most negatively influenced by policies. In this kind of set up it is far from obvious whether the just policy should be the one which minimises the net costs of the type with the highest responsibility (even if the population of this type bears the highest costs). In those situations, the previous criterion should be extended such that relative responsibility enters the just transition definition.

We propose to do this by applying what we call 'responsibility weights' across types, where each weight is inversely related to relative responsibility. In the extreme case whereby one type has all the responsibility, then the responsibility weight for this type will be equal to zero. In this case, the minimax criterion should be applied to the new 'weighted' types. Adding responsibility weights aims to equalise responsibility across types as such, while a different approach to this is to some extent equivalent to the purpose of defining types in Roemer's EOp. As Roemer (1998) mentions, the specific distinction of types at any setup is a political question as within a population, there can be disagreements about what should be considered a circumstance and what should not. These disagreements largely depend on people's differing ethical and

⁸ Note that as in the case in EOp we do not focus on the population size in each type.

⁹ This is also related to issues regarding restorative justice discussed in the next section.

⁷ We should note here that the maximin approaches are independent of the number of the worst-off individuals whose welfare should be maximised.

political points of view. In order to keep our approach as general as possible we have abstracted from providing any kind of criterion with respect to which types of responsibility regarding environmental damages should be informing the responsibility weights.

To show how responsibility weights enter our definition, consider the previous example with unequal responsibility between the types but with equal responsibility within types. More specifically, assume that the relative responsibility between S and N is $1/3$ and for H and L is the same. Based on the above, these correspond to responsibility weights $3/4$ for S , $1/4$ for N , and $1/2$ for both L and H . This means that the weighted costs for S and N are 7.5% and 1.25% while for L and H , the weighted costs are 6% and 1.5% respectively. In this setup, the just transition policy would be B .¹⁰ This leads to a further difference in the definition of types in comparison to EOp. We next turn to a general definition (or criterion) which captures the insights of our example.

Our characterisation of a just transition takes the form of an algorithm which leads to a minimax criterion that must be satisfied such that a transition policy can be labelled as just. The necessary steps to be able to apply the criterion are considering feasible policies with the same results and the corresponding distribution of relative net costs, calculating responsibility weights, and defining types based on relative costs and responsibility weights. To express this formally, consider the set of feasible policies $\Phi = \{p_1, p_2, \dots, p_K\}$, which can reach a given environmental target.

3.1. Types and costs

For each policy p_k , with $k = \{1, \dots, K\}$ define a set of types $I(p_k)$ based on the distribution of relative net costs $c^i(p_k)$, where $c^i(p_k)$ is the relative net costs incurred by type $i \in I(p_k)$ for a given policy p_k .

3.2. Responsibility weights

For each type $i \in I(p_k)$ compute the responsibility weight w^i , such that w^i is inversely related to type i 's relative responsibility and with $\sum [I(p_k)] w^i = 1$, where $|I(p_k)|$ indicates the cardinality of $I(p_k)$.

3.3. Max weighted costs

For each policy, p_k , find the maximum weighted net cost $c^i(p_k)w^i$ for each of the types and call this m^{p_k} .

3.4. Definition

We define as the just transition policy, the policy p_k^* which corresponds to the minimum m^{p_k}

$$p_k^* = \inf_{p_k \in \Phi} m^{p_k} \quad (1)$$

Linking this definition to our second example we have

- Policies: $\Phi = \{A, B\}$
- Types: $I(A) = \{N, S\}$ and $I(B) = \{L, H\}$
- Costs: $c^N(A) = 5\%$, $c^S(A) = 10\%$, $c^H(B) = 3\%$, $c^L(B) = 12\%$
- Responsibility weights: $w^N = 1/4$, $w^S = 3/4$, $w^H = 1/2$, $w^L = 1/2$
- Max weighted costs: $m^A = c^S(A)w^S = 7.5\%$ and $m^B = c^L(B)w^L = 6\%$
- Just transition policy: $\min \{m^A, m^B\}$, hence $p_k^* = B$

Note that in the definition above, types are defined by relative net costs and then responsibility weights, which are applied to each type, play the role of discounting the relative importance of (the costs faced

by) a type. However, there might be cases where responsibility is unequally distributed within a type. When the responsibility distribution is not very unequal it might be appropriate to apply to the whole population within a type an average responsibility weight. In cases where the distribution is very unequal, we should allow for different responsibility weights within a type, which in turn indirectly implies a further distinction of types into "sub-types" as the minimax criterion should be applied in the new weighted relative net costs. This means that for a set of feasible policies $\Phi = \{p_1, p_2, \dots, p_K\}$, costs $c^i(p_k)$ and types $I(p_k)$, first compute responsibility weights w^{ij} not only across types but also within types, where j captures the relevant sub-types. As before, the weights should be inversely related to the type and sub-type relative responsibility and be such that all weights add up to one. Then apply the new responsibility weights, find the maximum weighted relative costs and choose the policy with the lowest maximum relative cost.

4. Discussion

As mentioned in the introduction, a definition of a just transition should take into account not only distributive concerns but also incorporate procedural and restorative justice aspects (Newell and Mulvaney, 2013; McCauley and Heffron, 2018). As the two previous sections focused mainly on the distributive aspect of our definition, it is useful to discuss how our approach incorporates the other two justice aspects. By doing this we also aim to highlight links with other works within the broader environmental literature and also differences between our approach and theories of distributive justice presented earlier.

4.1. Procedural justice

Procedural justice is related to the processes and methods used to make decisions regarding allocation of resources and other disputes. Rawls (1971) distinguishes three forms of procedural justice: pure, perfect impure and imperfect impure. The key difference between pure and (both cases of) impure justice is that while for impure procedural justice, justice refers to the outcomes of a procedure, such that a process is just if its outcomes are just; according to pure procedural justice, a just procedure will lead to outcomes which should be considered just. The distinction between perfect and imperfect impure procedural justice has to do with whether the process can ensure that the outcome is just through the design of an appropriate procedure. While perfect impure procedural justice is such that the fair outcome can be guaranteed by a procedure, this is not true for the imperfect case. Rawls' theory of justice as fairness exhibits pure procedural justice (for a discussion see Freeman (2007)). Our proposed approach of minimising the highest relative average costs is a case of pure procedural justice. This is due to the fact that we define as just, the outcome of a specific process rather than designing a process which will lead to a specific ideal outcome. In this way, while from a distributive justice viewpoint our definition of just transition has important differences with the Rawlsian approach, there is an interesting link connecting the two approaches from the viewpoint of procedural justice.

Procedural justice can also relate to participation of the decision processes per se. Paavola (2004) emphasises that the process of decision-making must be inclusive and participatory, ensuring that all stakeholders, especially vulnerable and marginalised groups, have a voice in shaping policies that affect them. This participatory aspect of procedural justice is critical to the legitimacy and effectiveness of environmental policies (Schlosberg, 2007). Dryzek (2002) argues that fair and inclusive deliberation processes are necessary for legitimate and effective environmental policies. Participation and inclusiveness have an important role to play in our proposed framework as these are directly linked to the distinction of types. According to the EOp framework, the distinction of types is a political issue (Roemer, 1998) that consists in deciding which characteristics should be understood as circumstances beyond one's control is at least to some extent a political question. Bringing in this

¹⁰ Note that if there was unequal responsibility within types, this would imply that effectively more types would be defined, however for simplicity we abstract from this possibility.

political dimension allows Roemer (1998) to provide a definition of EOP leaving aside discussions regarding which characteristics should be viewed as circumstances. Even if this political aspect appears to be not so relevant in our *ex-post* type characterisation based on costs, there is still 'political' space to extend the number of types by considering relevant characteristics which have an impact on how we calculate costs and hence define types. Participation and inclusiveness are necessary conditions to ensure that relevant characteristics are taken into account when dividing the population into types. In this way, the participation dimension of procedural justice is not only embedded into our framework, but indirectly defines the process through which the just policies can be chosen.

4.2. Restorative justice

The academic landscape of *restorative justice* is rich and varied, with contributions from multiple disciplines, including Criminology, Sociology, Psychology, and Law focusing more on the positive (rather than the normative) side of the concept, linking it to broader social justice and human rights movements. A major aspect of restorative justice concerns restoring unjust inequalities. This aspect has been a key component of arguments in favour of a just transition since the start of the public debate on the topic in early 80's following unions' arguments restoring jobs in non-green industries lost due to a green transition (Stavis and Felli, 2015; Doorey, 2017; McCauley and Heffron, 2018). The rationale of this dimension of justice is that workers in non-green industries (will) have to bear very high costs by losing their jobs and finding a new one with low probability while their marginal responsibility for climate change is close to zero. Note that this is equivalent to arguing that these workers should not bear higher costs compared to other members of the society, especially given their lack of responsibility. From this viewpoint, this specific restorative justice concern is directly related to the luck egalitarianism debates and is already included in our just transition definition. Another aspect of restorative justice concerns inclusivity and participation and is directly linked to the second aspect of procedural justice discussed above. For example, Schlosberg and Craven (2019) discuss how restorative practices can support community-led sustainability efforts, enhancing both environmental outcomes and social justice. Motupalli (2018) argues for a paradigm shift in how international justice and environmental law intersect, advocating for restorative justice as a means to achieve more equitable and effective solutions to environmental problems.

A third aspect of restorative justice is related to the unequal (historic) responsibility of actors which should be taken into account. Notably, Hazrati and Heffron (2021) advocate for incorporating this aspect of restorative justice into the energy transition, emphasising the need to address historical and ongoing injustices associated with fossil fuels to ensure a fair and inclusive shift to renewable energy. They argue that by applying restorative justice to the energy transition, the scope of energy justice is broadened to include historical and social dimensions of energy production and consumption, and hence through this historical responsibility. This type of responsibility is captured in the responsibility weights, hence is incorporated in our definition. While including this aspect of justice is only important from a normative perspective it includes a political and a philosophical aspect as the answer to the question of how we can measure historical responsibility is far from a direct one. While these theories provide different frameworks which aim to equalise various *desiderata* focusing on the possible lack of responsibility regarding endowments (natural, social and/or economic) and preferences, here we allow for partial responsibility with respect to environmental damages.

5. Conclusion

Over the last three decades, scholars across fields and policymakers have argued that the transition should be socially just; however, without

a concrete definition regarding the criteria that policies should satisfy to be considered as just. This open question has been the motivation for this paper. We provide a formal definition regarding the conditions that should be satisfied for a low-carbon transition policy to be able to be considered just drawing on the principle that equal responsibility should lead to equal distribution of relative net costs. Then, from a set of feasible policies we label as just, the one which minimises the maximum relative net costs of a group of people as this will be the one moving closer to equalising relative costs. There are a number of issues we should highlight with respect to our definition. Note that our criterion does not directly propose how to design a policy but rather how to choose the just one from a set of available policies with the same impact. While we have left the explicit design of just policies as an avenue for future research, there are important direct policy implications following our definition. If for example only two policies are available it cannot be argued that none of these is just. However, as long as for a given set of policies there is unequal distribution of relative costs, in theory there could be a policy which could be superior in terms of our definition.

Our approach has been to provide a general proposition that can be applied to a variety of setups in both academic and policy analyses. By doing so, we have necessarily abstracted from a number of issues which can lead to further work in this field. In this sense we view our definition not as necessarily the unique one but as a starting point which while can provide a tool for analysis can be extended and reformulated to better fit different set ups. One important abstraction is related to the distinction of types and the computation of specific responsibility weights. Both issues have a political component similar to Roemer's distinction of types. With respect to unequal costs which define types in our approach, there can be (political) disagreements regarding how fine the division should be. For example, if a factory is closing down, should we consider the relative costs of all of the workers or should we also split them in smaller groups with different relative costs? Similarly in many situations, what should be considered as unequal responsibility is not straightforward. These types of questions can define directions for future research.

There are two further political economy issues related to our approach from which we have also abstracted but are very relevant especially with regards to the policy applications of our framework. These are related to both the targets and the set of policies into consideration. The targets differ across time and space; for example, the targets regarding the reduction of GHG emissions vary across countries, which in turn implies that the set of possible policies to achieve these targets will also differ. Also, targets depend on intergenerational ethical considerations which vary within the environmental economics literature. Including these considerations would require taking into account more types not only in the present but also further in the future.

Another issue that may deserve further inquiry is the timing of costs and benefits associated with transition policies. To the extent that costs of the transition are born in the short run and that benefits mainly emerge through time, the present discounted value of net costs depends very much on the discount rate that is (implicitly) applied by the various involved stakeholders. Societies characterised by varying degrees of short-termism would rank the same set of policies in different ways, as they would place different weights on future benefits vis-à-vis immediate costs. Finally, although in our definition we consider the set of feasible policies, we recognize that this feasibility constraint is also to some extent politically defined and linked to other economic, ecological (for example related to sustainability) and/or financial targets. While we have chosen to abstract from these to make our definition as general and applicable as possible, analysing how our just transition framework can change under different feasibility assumptions and targets, leads to another avenue of inquiry on the topic.

CRedit authorship contribution statement

Giorgos Galanis: Writing – original draft, Supervision,

Methodology, Formal analysis, Conceptualization. **Mauro Napoletano:** Writing – original draft, Investigation, Conceptualization. **Lilit Popoyan:** Writing – original draft, Supervision, Methodology, Formal analysis, Conceptualization. **Alessandro Sapio:** Writing – original draft, Investigation, Formal analysis, Conceptualization. **Olivier Vardakoulis:** Writing – original draft, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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