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The global carbon budget: a conflicting claims problem

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Abstract An effective climate agreement is urgently required, yet conflict between parties prevails over cooperation. Thanks to advances in science it is now possible to quantify the global carbon budget, the amount of available cumulative CO_2 emissions before crossing the 2 °C threshold (Meinshausen et al. Nature 458(7242):1158–1162, 2009). Countries carbon claims, however, exceed this. Historically such situations have been tackled with bankruptcy division rules. We argue that framing climate negotiations as a classical conflicting claims problem (O'Neill Math Soc Sci 2(4):345–371, 1972) may provide for an effective climate policy. We analyze the allocation of the global carbon budget among parties claiming the maximum emissions rights possible. Based on the selection of some desirable principles, we propose an efficient and sustainable allocation of the available carbon budget for the period 2000 to 2050 taking into account different risk scenarios.

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1 Introduction

Climate change can be seen as the result of an unsolved carbon budget bankruptcy. Limiting the global cumulative CO_2 to 1,440 Gt, over the period 2000–2050, would yield a 50 % probability of exceeding the 2 °C of the average temperature above pre-industrial levels (Meinshausen et al. 2009). However, it is estimated that the world's cumulative emissions for the period in question will range from 1,758 to 2,736 Gt (IPCC 2000). Consequently, environmental global governance will find itself in a situation of carbon bankruptcy: countries will have claimed more cumulative emissions (1,758–2,736 Gt) by 2050 than those actually available.

Situations like this are known as conflicting claims problems (O'Neill 1982): different agents claim the scarce resources so that there are not enough resources to honor the aggregate claim. The typical example is how the money in a bankrupted firm should be distributed among its creditors, but the utility of conflicting claims theory has been shown in a variety of areas such as medical assistance, budget distribution in universities, milk quota distribution among EU member states, the distribution of seats in parliament in the USA or Spain, see Giménez-Gómez and Peris (2014) or in environmental issues such as the reduction of fishing quotas (Iñarra and Prellezo 2008). The body of literature on conflicting claims problems has provided different ways to solve these sorts of problems, often expressed in terms of rules. So far, climate change negotiations have not been considered from this perspective, despite this being a fitting approach. In this paper we argue that tackling climate change negotiations as a conflicting claims problem is potentially a more effective tool than the more usual agreement-dependent approaches.

The endowment (the resources to be distributed) is the available carbon budget. We use the probabilistic model of Meinshausen et al. (2009) where different carbon budgets with different associated risks are provided for the period 2000–2050. The creditors (the agents claiming the resources) are represented by the emitting countries. Their aggregate claims cannot be fully satisfied by the available carbon budget. Countries' claims are approximated by the emissions' projections made by the IPCC for different world regions (IPCC 2000): specifically, we use the A1FI scenario, as it is the most carbon intense, and we assume that most natural behavior for countries, in a carbon bankruptcy framework, would be to claim their maximum emissions. These claims can be interpreted as (i) the maximum amount of emissions' rights a country could claim for; or (ii) the cumulative emissions that would be emitted in the case that a commitment to cooperate was not achieved (Frame and Hepburn 2012). However, real claims could be different to those used here. Indeed, probably one of the main contributions of this approach to climate negotiations from a conflicting claims problem is that parties are free to make their carbon claims. The Intended Nationally Determined Contributions (INDC) in the Paris agreement respond to this same logic. Then, considering the different risk scenarios of exceeding the 2 °C limit, we allocate available cumulative emissions by using rationing techniques.

The article aims to provide insights useful for constructing a successful climate policy architecture. The model proposed involves a carbon budget, which makes it environmentally effective, and secondly, it allows parties to determine their own carbon claims, which makes it less agreement-dependent. Our analysis assesses (i) different rules for the distribution of the global carbon budget, and (ii) different desirable principles that this rules may require in the climate change context. Our analysis suggests that the most adequate division rule satisfying all the required principles to deal with a conflicting claims problem involved in climate change is the Talmud rule: a division rule that takes its name from the Babylonian Talmud, a compendium of Jewish laws that dates back 1,800 years.

The paper is organized as follows. Section 2 provides an overview on climate change policy and reviews the related literature. Section 3 defines the CO_2 associated conflicting claims problems. Section 4 presents different possible rules for distributing the carbon budget. Section 5 proposes how carbon budget should be distributed in terms of general and widely-accepted principles of fairness. Section 6 presents concluding remarks.

2 Climate change policy and the carbon budget approach

In recent years, because it is consistent with climate change mitigation, there is growing scientific agreement that climate policy (and hence climate negotiations) should be framed in terms of cumulative emissions and on a fixed global carbon budget rather than in terms of annual emissions (WGBU 2009; Bretschger 2013; IPCC 2013, 2014; Frame et al. 2014; Grasso and Roberts 2014; Raupach et al. 2014). The carbon budget approach guarantees that the main object of climate change policy, which is the raising of temperature, is actually pursued.

Nonetheless, the scientific support to frame climate policy on the carbon budget approach collides with realistic politics. The required global cooperation (Beccherle and Tirole 2011; Vasconcelos et al. 2013) has traditionally been hampered by global inequalities between countries (Duro and Teixidó-Figueras 2014), and a carbon budget framework would possibly bring further disagreement.

Hence, given the consistency of the carbon budget approach on the one hand, and the arduous nature of global cooperation on the other, approaching these negotiations from the framework of the conflicting claim problem, which was in fact historically conceived to solve conflicting situations of bankruptcy, appears to be at least a reasonable way to tackle climate change negotiations. This is specially when disagreement prevails as a bankruptcy model is a conflicting game.

2.1 Literature review

After the end of the first commitment period of the Kyoto protocol in 1997, many climate change policy architectures have been proposed to allocate emissions rights (see IPCC 2014, Chapter 13). Here, we focus on those architectures framed on the allocation of emissions rights provided that a carbon budget approach is considered, in doing so we situate the position of our contribution.

The first approach in which carbon budget allocation is dealt with, stems from ethical considerations. In this regard, as Caney (2009) put it, the most frequently applied method to allocate emissions rights is the so-called grandfathering criteria, where the quota is proportional to the current share of emissions. Notwithstanding, this is assumed to be an unjust criteria from the standpoint of any moral or political stance (Caney 2009, p. 128) and in practice it is often invoked by major emitters. However, from an ethical perspective it is Grasso (2012) who first discusses different distributive patterns in a carbon budget approach. He considers population-based, GDP-based and emissions-based criteria to allocate available cumulative emissions. In general, he found that population-based patterns (i.e. allocating quotas in terms of the population share) tend to favor southern countries, specially those where a sufficiency threshold of emissions is taken into account, whereas GDP-based and emissions-based criteria tend to favor northern counties. Along a similar line, Bretschger (2013) formalizes a carbon budget by calculating a fairness index based on equity principles.

A different approach to allocate the carbon budget is provided by Llavador et al. (2015) who model an inter-generational North-South world where a sustainable emissions pathway has already been agreed a priori between both North (represented by the USA) and South (represented by China). From there, the authors allocate CO_2 emissions in terms of the growth rates of North and South, which converge to 1–2.5 % per year. Raupach et al. (2014) propose a spectrum of sharing principles of the available carbon budget that extends from per capita distribution (total equity, and hence prohibitive for developed countries) to a grandfathering distribution (inertia, and hence prohibitive for least developed countries). The authors conclude that a blend of the two extremes is the most viable option. Finally, urged by the need for international cooperative action, Grasso and Roberts (2014) propose an already-defined climate architecture consisting in framing a carbon budget policy between 13 major economies (as they account for 81 % of global emissions) and on cumulative consumption-based emissions. They allege this framework would ease the negotiations.

The policy architecture proposed in this paper is also aimed at allocating the remaining carbon budget among countries in a UNFCCC negotiating context. In our framework, however, parties does not need to agree ex ante on an optimal allocation procedure (in contrast to previous literature); countries can claim the budget share according to what they consider more relevant: some may claim on a population basis while others may claim on grandfathering.[1] Then, what matters is that the available carbon budget is not enough to satisfy all claims. We argue that this is actually closer to reality: namely, conflict rather than agreement.

We depart from the basis of a conflicting claims problem so that we can benefit from techniques that have already proven useful in other similar bankruptcy situations. What is to be discussed here is which division rule should be considered in the bankrupt carbon budget, and which properties should configure those division rules. We understand that this provides a more robust discussion since results cannot be that easily biased with respect to particular interests, as easily happens in purely ethical discussions. In this regard, Finus and Pintassilgo (2013) shows that a 'veil of ignorance' in international climate negotiations, which means that distributional output is unknown for participants, might be conducive to the success of international cooperation.

Note, however, that the approach proposed is not irreconcilable with previous proposals in the literature of carbon budget allocations. On the contrary, if a particular allocation rule were agreed between parties, the rationing approach proposed can be seen as a tool to ease global environmental governance, since country allocations are not limited ex ante by the carbon budget, but ex post by the rationing rule.

3 The CO_2 associated conflicting claims problem

Consider a set of agents $N = \{1, 2, ..., n\}$ and an amount $E \in \mathbb{R}_+$ of an infinite divisible resource, the **endowment** or budget, that has to be allocated among them. Each agent has a **claim**, $c_i \in \mathbb{R}_+$ on it. Let $c \equiv (c_i)_{i \in N}$ be the claims vector.

[1]Intended Nationally Determined Contributions (INDC) in the Paris agreement in 2015 follows this logic. Each country's pledge is based on heterogeneous criteria.

A **claims problem** is a pair (E, c) with $C = \sum_{i=1}^{n} c_i > E$. Without loss of generality, we order the agents according to their claims, $c_1 \leqslant c_2 \leqslant \ldots \leqslant c_n$, and we denote by $\mathcal{B}$ the set of all claims problems.

The endowment is determined by the amount of available anthropogenic cumulative CO_2 that prevents the global temperature from exceeding 2 °C: our carbon budget taken from Meinshausen et al. (2009). Specifically, we consider three different carbon budgets for the period 2000–2050: (a) 1, 440 Gt CO_2 which corresponds to a 50 % probability of exceeding 2 °C threshold; (b) 1, 000 Gt CO_2 which corresponds to a 25 % probability; and (c) 745 Gt CO_2 as a budget where, according to current knowledge, the probability of exceeding 2 °C is 0. Budgets (a) and (b) are considered sensible by the scientific community and policymakers (Rockstrom et al. 2009) being managed in both Worlds. Budget (c) allows for a zero-risk scenario.

To define agents' claims, we use the future cumulative CO_2 projected by the SRES of the IPCC as a proxy of what countries might claim. Specifically, we use the fuel-intensive A1FI IPCC scenario in which countries claim the maximum they can. Global cumulative emissions will amount to 2, 736 Gt CO_2 by 2050 (higher than any of the carbon budgets considered). We assume that in the real world, countries will claim as many emission rights as they can, especially when carbon market frames are considered. Countries will justify their claims by using the criteria that best adapts to their needs (i.e. population-based, emission-based, etc.) and it is this conflict of interests, in fact, that impedes usual climate agreements. By using the worst future scenario, we intend to approximate the feasible behavior of the countries in such a context. Note, however, that other definitions of claims could be fitted to the model: attending population-share, emission-share, capacity to reduce emissions, etc. In this cases different allocations would be obtained. Further, claims can also be interpreted as the outcome of a non-agreement situation (Frame and Hepburn 2012).

The set of claimants is composed by the four World SRES groups typically considered in climatic models (see Figure 1 in the electronic supplemental material): OECD countries as in year 1990 (OECD90), Asia (ASIA), Africa and Latin America (ALM), countries undergoing economic changes (REF). Note that OECD90 and REF countries roughly correspond to Annex I countries of UNFCCC, countries that commit reductions targets in the Kyoto Protocol, while ASIA and ALM roughly correspond to developing countries of non-Annex I group (see IPCC 2000)[2] Alternatively, OECD90 and REF countries can also be regarded as the Global North (rich countries) and ASIA and ALM as Global South (poor countries).

4 How can the global carbon budget be distributed? Rules

Given a conflicting claims problem, a rule proposes an allocation of the endowment among the claimants by satisfying the following requirements:

[2]Given the purpose of this article, the authors would have considered further decomposition of the groups used as agents, however, the only regional decomposition for future cumulative emissions is only available at IPCC (2000). Although other possibilities such as the more recent RCP-database have been considered, to the best of our knowledge no database other than SRES-IPCC decomposes cumulative emissions by groups of countries.

A rule is a single-valued function $\varphi : \mathcal{B} \rightarrow \mathbb{R}^n_+$ such that $\varphi_i(E, c) \geqslant 0$, for all $i \in N$ (**non-negativity**), $\varphi_i(E, c) \leqslant c_i$, for all $i \in N$ (**claim-boundedness**), and $\sum_{i=1}^{n} \varphi_i(E, c) = E$ (**efficiency**).

This formal analysis (O'Neill 1982) provides a vast number of well-behaved rules, being the proportional, the constrained equal awards, the constrained equal losses and the Talmud rules the prominent ones. The choice of these solutions is by no means arbitrary (Herrero and Villar 2001): they are the most common methods of solving actual conflicting claims problems; and they are almost the only sensible ones within the family of solutions that treat equal claims equally (Moulin 2002; Thomson 2015).

The **proportional (P)** rule recommends for each $(E, c) \in \mathcal{B}$ and each $i \in N$, $P_i(E, c) \equiv \lambda c_i$, where $\lambda = E / \sum_{i \in N} c_i$.

The P is the best-known and most actually used rule. It divides the carbon budget proportionally with respect to each region's claim.

The **constrained equal awards (CEA)** rule (Maimonides 2000), proposes for each $(E, c) \in \mathcal{B}$ and each $i \in N$, $CEA_i(E, c) \equiv \min\{c_i, \mu\}$, where μ is such that $\sum_{i \in N} \min\{c_i, \mu\} = E$.

The CEA proposes an equal distribution of the cumulative CO_2 emissions. However, CEA does not consider the differences between countries in terms of lost emissions rights.

The **constrained equal losses (CEL)** rule (Maimonides 2000; Aumann and Maschler 1985) chooses for each $(E, c) \in \mathcal{B}$ and each $i \in N$, $CEL_i(E, c) \equiv \max\{0, c_i - \mu\}$, where μ is such that $\sum_{i \in N} \max\{0, c_i - \mu\} = E$.

The CEL recommends an egalitarian distribution of the losses incurred (the part of the aggregate cumulative CO_2 emissions that is not satisfied, i.e. $L = C - E$), given that no one can emit a negative amount. This rule procures an egalitarian division of regional sacrifices. However, this may involve not allocating emissions rights to lower claimants, which cannot be done for ethical or economic reasons.

The **Talmud (T)** rule (Aumann and Maschler 1985) recommends for each $(E, c) \in \mathcal{B}$, and each $i \in N$, $T_i(E, c) \equiv CEA_i(E, c/2)$ if $E \leqslant C/2$; or $T_i(E, c) \equiv c_i/2 + CEL_i(E - C/2, c/2)$, otherwise.

"It is socially unjust for different creditors to be on opposite sides of the halfway point, $C/2$" (Aumann and Maschler 1985). Since T is a combination of CEA and CEL, it takes the middle of the aggregate claims as a reference point. If the half of the total needs of cumulative CO_2 emissions is lower than the carbon budget, then the CEA is applied over the half-claims; whereas, each region receives half of its expected emissions and the amount recommended by CEL, otherwise.

Table 1 summarizes the comparison among the proposed rules and the three different considered carbon budgets. As aforementioned, we consider four regions (agents) and the proposed CO_2 emitting rights in a 50-year period (budget allocations).[3]

[3] For the sake of clarification, Figures 2, 3 and 4 in the electronic supplemental material, provide the vessels representation of each region's honored claims.

Table 1 Cumulative CO_2 emissions allocations

Claims: REF = 300.36; ALM = 618.78; OECD90 = 768.47; ASIA = 1,048.57

		P	*CEA*	*CEL*	*T*
Budget	REF	158.07	300.36	0	150.18
1, 440 Gt	ALM	325.65	379.88	286.84	309.39
CO_2	OECD90	404.43	379.88	436.53	384.24
(50 %)	ASIA	551.84	379.88	716.63	596.2
Budget	REF	109.77	250	0	150.18
1, 000 Gt	ALM	226.15	250	140.17	283.27
CO_2	OECD90	280.86	250	289.86	283.27
(25 %)	ASIA	383.22	250	569.96	283.27
Budget	REF	81.78	186.25	0	150.18
745 Gt	ALM	168.48	186.25	55.17	198.27
CO_2	OECD90	209.24	186.25	204.86	198.27
(0 %)	ASIA	285.5	186.25	484.96	198.27

Brackets, the probability of exceeding 2 °C (Meinshausen et al. 2009). Rows provide the allocations recommended by each of the four considered groups: OECD countries as in 1990 (OECD90), Asia (ASIA), Africa and Latin America (ALM), countries undergoing economic changes (REF). Columns show the allocations recommended by each rule for each group

5 How should the global carbon budget be distributed? Principles

We use the conflicting claims approach to focus the discussion about global governance of climate change on the "sensible" principles behind the rules, rather than on quantitative allocations of cumulative CO_2 emissions. Since the principles are exogenous to the allocations propose by the rules, these should be defended via principles or appealing properties that all the involved groups may exogenously accept. Accordingly, different rules can be regarded as implementing different equity and operational principles. Whereas equity principles specify desirable properties that translate some value judgements into distributional results under certain circumstances, operational principles are typically invariance properties with respect to change in the parameters of the problem. The axiomatic approach aims at identifying each rule with a set of well-defined principles, so that choosing a rule means solving the problem by applying these principles (see Herrero and Villar 2001). Next we present the principles usually considered relevant that behave naturally in this context.

Equal treatment of equals implies that agents with equal claims should receive the same awards: for each $(E, c) \in \mathcal{B}$, and each $\{i, j\} \subseteq N$, if $c_i = c_j$, then $\varphi_i(E, c) = \varphi_j(E, c)$.

This property says that the same emitting needs should be rewarded with the same cumulative CO_2 allocation.

Anonymity states that the awards received by an agent should depend only on her claim, and not on her identity: for each $(E, c) \in \mathcal{B}$, each $\pi \in \Pi^N$, and each $i \in N$, $\varphi_{\pi(i)}(E, (c_{\pi(i)})_{i \in N}) = \varphi_i(E, c)$, where Π^N is the class of all permutations of N.

Anonymity implies that the identity of the claimant does not matter, so a region's emission rights should only depend on its stated emitting needs (claimed emissions).

Order preservation (Aumann and Maschler 1985) requires respecting the ordering of the claims, i.e. if agent $i's$ claim is at least as large as agent $j's$ claim, she should receive and lose at least as much as agent j does, respectively: for each $(E, c) \in \mathcal{B}$, and each $i, j \in N$, such that $c_i \geqslant c_j$, then $\varphi_i(E, c) \geqslant \varphi_j(E, c)$,and $c_i - \varphi_i(E, c) \geqslant c_j - \varphi_j(E, c)$.

Order preservation asserts the regions with greater emissions should not receive a smaller allocation than the regions with smaller emitting needs.

Self-duality (Aumann and Maschler 1985) implies that the problem of dividing "what is available " or "what is missing " should give the same awards: for each $(E, c) \in \mathcal{B}$ and each $i \in N$, $\varphi_i(E, c) = c_i - \varphi_i(\sum_{i \in N} c_i - E, c)$.

Self-duality looks at the problem from two opposite perspectives: from "what is available" (the obtained awards) and from "what is missing" (the not honoured part of the claim). Consider, for instance, $E = 1,440$, so $L = 2,736.18 - 1,440 = 1,296.18$. Then, $P(L, c) = (142.29; 293.13; 364.04; 496.73)$, so the allocation proposed would be obtained by subtracting the incurred losses from the claims, $c - P(L, c) = (300.36; 618.78; 768.47; 1,048.57) - (142.29; 293.13; 364.04; 496.73) = (158.07; 325.65; 404.43; 551.84)$, which coincides with the proposed P on awards (see Table 1). The advisability of this principle stems from the fact that countries might consider the carbon allocation an award (CO_2 they can emit) or a loss (CO_2 they cannot emit). In both cases, whether they negotiate awards or losses, the result is the same for rules satisfying this principle. In a context of international negotiations, this principle results very convenient as it might ease agreements. Moreover, this property implies that no region will receive more than half of its claim if the rest of the regions have not yet received theirs.

Claims truncation invariance (Dagan and Volij 1993) says that truncating claims at the endowment should not affect the recommended award vector: for each $(E, c) \in \mathcal{B}$, and each $i \in N$, $\varphi_i(E, c) = \varphi_i(E, \min\{c_i, E\}_{i \in N})$.

Claims truncation invariance refers to the upper bound for emitting quotas. It says that those claims that are over the global carbon budget should not be rewarded. Hence the allocation should not depend on that part of the claim that is greater than the total amount to divide. In order to see what this property implies in our conflicting claims problem we can analyze the proposed rules in Table 1 in two different cases. Note that when the budget is 1,000 G_t CO_2, claims truncation implies that $ASIA$ reduces its claim from 1,048.57 G_t CO_2 to 1,000 G_t CO_2. Under this assumption we obtain Table 2. We observe that there are no any big changes, but all the groups increase their allocations a little except $ASIA$ which decreases the amount it receives for all the rules except for CEA and T. And, analogously when $E = 745$ (see Supplementary Material). So that, the claims truncation invariance helps agents to have a closer connection to the atmosphere sink capacity.

Consistency states that if some agents leave the problem, the remaining agents should not be affected: for each $(E, c) \in \mathcal{B}$ and each $N' \subset N$, if $x = \varphi(E, c)$, then $x_{N'} = \varphi(\sum_{N'} x_i, c_{N'})$.

This property makes the rule invariant to partitions and mergers of claimants. If we partition the regions into two or more smaller regions, the initial allocation of CO_2 emissions rights will remain valid. For instance, if the $OECD$ region splits into two more regions, consistency implies that the other regions will receive the initial CO_2 emissions rights, and the sum of the two new regions' CO_2 emissions rights will coincide with the $OECD$'s. Additionally, bilateral consistency is a weaker version of consistency by restricting attention to subgroups of two remaining claimants.

Minimal rights first (Curiel et al. 1987) states that each agent should receive no less than the minimal right lower bound, so the rule should recommend the same allocation either directly or assigning the minimal right firstly: for each $(E, c) \in \mathcal{B}$, the vector of

Table 2 Claims truncation with $E = 1,000$

	P	CEA	CEL	T
Initial claims: REF = 300.36; ALM = 618.78; OECD90 = 768.47; ASIA = 1,048.57				
$E = 1,000$				
REF	109.77	250	0	150.18
ALM	226.15	250	140.17	283.27
OECD90	280.86	250	289.86	283.27
ASIA	383.22	250	569.96	283.27
By claims truncation, adjusted claims: REF = 300.36; ALM = 618.78; OECD90 = 768.47; ASIA = 1,000				
REF	111.76	250	0	150.18
ALM	230.23	250	156.36	283.27
OECD90	285.93	250	306.05	283.27
ASIA	372.08	250	537.58	283.27

minimal rights is $m(E, c) = (m_i(E, c))_{i \in N}$ where $(m_i(E, c) = \max\{E - \sum_{N \setminus i} c_j, 0\}$. Then, $\varphi(E, c) = m(E, c) + \varphi(c - m(E, c), E - \sum_{i \in N} m_i(E, c))$.

Note that this principle establishes a minimal level of emission rights for each region, since it works as a lower bound. Firstly, for each claimant we identify an amount considered to be a minimum right (the difference between the carbon budget and the remaining claimed emissions right if it is non-negative, and zero otherwise). Then, each region receives its minimal right, and the CO_2 conflicting claims problem is revised to distribute the remaining carbon budget by applying the rule.

Looking at the climate change problem as a conflicting claims problem may generate positive synergies while requiring little or no agreement. In this regard, the Talmud rule is the only one of the common division rules that implements all the desirable principles of a carbon budget negotiation, and, hence, it is the rule that best performs in this new frame. Furthermore, the Talmud rule does not only satisfy all the desirable principles; it is the only rule that fulfils equal treatment of equals, claims truncation invariance, minimal rights first, and bilateral consistency (see Thomson 2006, Theorem 4.10, for this full characterization of the Talmud rule). Next, Table 3 shows which properties are satisfied by the considered rules.

Table 3 Principles and rules

Principles/rules	P	CEA	CEL	T
Equal treatment of equals	Yes	Yes	Yes	Yes
Anonymity	Yes	Yes	Yes	Yes
Order preservation	Yes	Yes	Yes	Yes
Claims truncation invariance	No	Yes	No	Yes
Self-duality	Yes	No	No	Yes
Bilateral consistency	Yes	Yes	Yes	Yes
Minimal rights first	No	No	Yes	Yes

Each column corresponds with a rule, whereas each row corresponds with the proposed principle. For more details see Thomson (2015)

6 Conclusions

The paper presents climate change negotiations as a well-defined conflicting claims problem. Countries claim for a particular amount of emissions rights that unfortunately are higher than the total emissions rights available in the global carbon budget. This is a conflicting claims problem that requires discussion on which division rule should be applied. Our analysis consists therefore in addressing the concern over climate change from the approach of a conflicting claims problem. We consider the case of an available carbon budget of 1,400 Gt, 1,000 Gt and 745 Gt over the period 2000–2050 (in order to have only, respectively, a 50 %, 25 % or 0 % probability of not exceeding climate thresholds), whereas all countries together are projected to emit 2,736 Gt of cumulative CO_2 by 2050. As a result, we show how bankruptcy techniques emerge as a very useful and suitable tool to deal with climate negotiations. After discussing the main division rules of the relevant literature, we propose a set of desirable principles that better adapt to global carbon bankruptcy. The Talmud rule, a rationing division rule that dates back 1,800 years, appears to be the only proposed rule that takes account of all these principles.

We argue that approaching climate change negotiations as a classical conflicting claims problem carries three positive implications for global climate policy: firstly, it allows us to undertake a global mitigation policy without requiring countries to agree on who should reduce emissions and by how much. Instead, as in the case of any bankruptcy situation, the focal point is on how much of the claim can the party get, rather than on differentiated responsibilities. Secondly, this conflicting claims model is framed on a carbon budget approach - what makes climate policy more effective as it deals with cumulative emissions rather than with annual emissions - and hence, the climate policy becomes more consistent with the temperature raising objective. Last but not least, we show that, assuming countries' claims consist of a future emissions' path where countries would not reduce emissions (A1FI scenario), the allocation of the carbon budget favours Kyoto's non-annex I countries, i.e. developing countries.

As a possible extension of this work, we could analyze the same problem as a dynamic conflicting claims problem and as a cooperative game. In this case the Talmud rule coincides with Nucleolus (Schmeidler 1969), a well-known solution for cooperative games.

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