Climatic Change
DOI 10.1007/s10584-013-0764-x

Why geoengineering is not a 'global public good', and why it is ethically misleading to frame it as one

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Received: 3 December 2012 / Accepted: 4 April 2013
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Abstract In early policy work, climate engineering is often described as a global public good. This paper argues that the paradigm example of geoengineering—stratospheric sulfate injection (hereafter 'SSI')—does not fit the canonical technical definition of a global public good, and that more relaxed versions are unhelpful. More importantly, it claims that, regardless of the technicalities, the public good framing is seriously misleading, in part because it arbitrarily marginalizes ethical concerns. Both points suggest that more clarity is needed about the aims of geoengineering policy—and especially governance—and that this requires special attention to ethics.

1 Introduction

Serious discussion of geoengineering – roughly "the intentional manipulation of planetary systems at a global scale" - is in its infancy; hence, it is especially important how the issue is framed. In early policy work, geoengineering is often described as a global public good. This paper challenges that classification.

First, it argues that the paradigm example of geoengineering - stratospheric sulfate injection (hereafter 'SSI')[1] - does not fit the canonical technical definition of a global public good, and that more relaxed versions are unhelpful.

Second, and more importantly, it claims that, regardless of the technicalities, the public good framing is seriously misleading, in part because it arbitrarily marginalizes ethical

[1]The assumption that SSI is a paradigm case is so universal that it is often the only case considered in the public good analysis. Moreover, while the public good analysis might succeed for other technologies (e.g., carbon dioxide removal), this requires argument given the massive scale of intervention needed (Gardiner 2011, 343–345).

This article is part of a special issue on "Geoengineering Research and its Limitations" edited by Robert Wood, Stephen Gardiner, and Lauren Hartzell-Nichols.

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Published online: 09 May 2013

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2 The public good framing

The term 'global public good' has become a "key concept in international development" and the "buzzword" of the last decade (Carbone 2007). In his canonical treatment of global public goods, Scott Barrett includes geoengineering in his "simple taxonomy of global public goods" (Barrett 2007, table 1.1; 7, 40–41), and both he and Dan Bodansky describe SSI as "a single-best-effort public good" (Barrett 2007, 38; Bodansky 2012, 23–24). Similarly, the first of the influential Oxford Principles declares that geoengineering is "to be regulated as a public good" for all humanity (Rayner et al. 2009, 2013), and versions of this principle have been endorsed by the Asilomar conference (MacCracken et al. 2010), an editorial in *Nature* (Nature 2012), and the government of the United Kingdom (UK Government 2010).

The crucial phrases have technical meanings in international relations and economics. First, a pure public good is a good that satisfies two conditions. It is nonrival: one person's consumption of the good does not inhibit another person's consumption. It is also nonexcludable: once it is available to some, others cannot be prevented from consuming it.

These conditions are uncontroversial in the geoengineering context. For example, in defining global public goods, Barrett states:

> "Global public goods offer benefits that are both nonexcludable and nonrival. Once provided, no country can be prevented from enjoying a global public good; nor can any country's enjoyment of the good impinge on the consumption opportunities of other countries." (Barrett 2007, 1)

Similarly, the lead author of the Oxford Principles, Steve Rayner, claims: "Geoengineering should be pursued as a public good and treated as non-rivalrous and non-excludable" (Rayner 2011, 11).

Second, it is common to assume that genuine public goods benefit everyone. Indeed, Barrett includes universal benefit in his definition of global public goods, stating immediately after the above:

> "When provision succeeds, global public goods make people everywhere better off. Global public goods are thus universally to be desired." (Barrett 2007, 1)

Relatedly, the authors of the Oxford Principles claim that "the principle that geoengineering should be regulated as a public good … suggests that the global climate must be managed … for *the benefit of all*" (Rayner et al. 2013; emphasis added).

Third, a "single best effort" public good is one where only one successful intervention is required (Barrett 2007, 3), and where this can often be achieved by an individual actor or small group (Bodansky 2012, 20).

The intuitive idea behind these various claims becomes clearer if we look at a standard—albeit idealized—paradigm case.[2] Imagine a small community of sailors who, being threatened by rocks near their home port, decide to build a lighthouse. The lighthouse benefits all of them: everyone is able to see the rocks, and so to avoid them. Consumption is nonrival:

[2] The use of the lighthouse as a paradigm does not imply that *all* lighthouses are pure public goods. The motivating idea is that there is a readily imaginable (though perhaps rare) circumstance where a lighthouse would be a pure public good for some community.

one sailor's seeing the rocks has no negative implications for any another's ability to do the same thing, and *vice versa*. It is also nonexcludable: once the light is there to aid one sailor, it is available to everyone, whether the others like it or not. Finally, provision can be achieved with a single best effort. Only one lighthouse is required. Once the light is there, everyone can see the rocks, and additional lighthouses are not only unnecessary, but also wasteful.

2.1 Implications

Normally, framing something as a public good—and so as relevantly similar to the paradigm lighthouse—has significant implications for public policy.

On the one hand, it affects how the problem is understood. Traditionally, the primary concern is with underprovision (e.g., Stiglitz 2000, 79–80, 129). Since those who produce the good cannot prevent others from consuming it, they cannot ensure that they contribute to the costs, and so may prefer not to produce, or not to produce enough. Similarly, at the outset of his book, Barrett argues that we should care about global public goods because failure to supply them "exposes the world to great dangers", and "our well-being, the well-being of future generations, and even the fate of the Earth depends on their being provided" (Barrett 2007, 1).

On the other hand, the framing is encouraging about solutions. First, given the universal benefit claim, it is common to assume that *no one has (good) reason to object* to the supply of a global public good. For example, Barrett states that if a global public good is universally welcomed, then it does not matter if providers fail to seek the permission, or even to consider the interests, of nonproviders (Barrett 2007, 23, 46).

Second, in 'single best effort' cases, *widespread cooperation is often unnecessary*. For example, a small group of rich sailors may build the lighthouse even without the cooperation of others, either because taking on all the costs themselves is better for them than risking the rocks, or because they are committed to saving lives. Consequently, Barrett claims that SSI is easier to implement geopolitically than emissions reduction, since the latter constitutes a different kind of global public good that requires almost universal cooperation (Barrett 2007).[3]

Third, the *apparent unfairness to providers need not undermine provision*. For example, the small group of rich sailors may resent other sailors for free riding, but that need not stop the project. Indeed, if they proceed anyway, and so freely accept the unfairness, the moral objection to allowing provision is weaker than it might otherwise be.

Fourth, often there is *a case for state provision*, even if this involves coercion. For example, in domestic cases, there is a strong tradition of government arranging and enforcing provision for the benefit of all (e.g., Stiglitz 2000, 80; Barrett 2007, 15).

In summary, even given the background worry about underprovision, framing something as a "single best effort" global public good usually suggests a rosy picture for public policy. In a paradigm case such as the lighthouse, a pure public good promises to benefit all with no negative implications for anyone. Given this, it seems that no one has good reason to oppose provision, that some may be motivated to provide even accepting that others will free ride, and (failing that) that there are strong reasons to endorse state provision, even if this involves coercion. Framing something as a best effort global public good is thus no small thing.

Unfortunately, this rosy picture is deeply misleading when it comes to geoengineering. SSI shares neither the central characteristics of a global public good as normally understood, nor the implications for provision. Moreover, the framing distorts our understanding of our predicament by obscuring ethical considerations that ought to be central to geoengineering policy.

[3] Some of my objections also count against treating emissions reductions as a global public good (cf. Stern 2007).

3 Universal benefit?

Barrett asserts that global public goods benefit everyone and that they do so by definition (see also Kaul et al. 1999, 6, 11, 510; Kaul and Conceicao 2006, xii). Call this, 'the broad account' of global public goods.[4] This section considers whether the universal benefit claim is plausible for geoengineering.

3.1 Descriptive claim?

The universal benefit claim is most naturally taken as a generic descriptive assertion about geoengineering considered simply *as such*. Unfortunately, this assertion is false. 'Geoengineering' is commonly defined as "intentional, large-scale manipulation of the environment" (Keith 2000), or more narrowly as "deliberate large-scale intervention in the Earth's climate system, in order to moderate global warming" (Shepherd et al. 2009). However, there is no reason to believe that *every* activity that might satisfy such generic definitions will benefit everyone, whether we are talking about nations, other groups, or individuals. There is nothing magical about technological interventions in the Earth's basic systems that implies (let alone guarantees) universal benefit. Instead, some interventions would be bad for everyone (e.g., interventions that bring on severe runaway climate change), and others would have substantial negative impacts on at least some of those affected. Given this, it is a mistake simply to assume that geoengineering necessarily benefits all those affected. Moreover, to do so assumes away some of the most important criticisms of proposed interventions, namely that they pose high risks of serious negative impacts. The generic descriptive account therefore fails.

Barrett sometimes recognizes that things he describes as global public goods might not produce universal benefits. For example, in discussing single best effort cases, he says:

> "If provision [of a global public good by one or a small number of countries] [a] introduces new risks, or [b] harms some countries even as it benefits others, or [c] affects the incentives to supply related public goods, then [d] governance becomes an issue." (Barrett 2007, 23; letters added)

Hence, he seems explicitly to consider violations of the universal benefit claim [a, b and c], and to suggest a remedy [d].[5]

There are several possible interpretations of what Barrett is doing here, but none is entirely happy. The first is the least charitable. He violates his own definition: if provision of X *harms* some countries, then X is not universally beneficial, and so is not a global public good on the broad account.

A more charitable interpretation is that Barrett believes that the complications affect the magnitude of the benefit to each party without undermining the claim that all receive *net* benefits. Unfortunately, in the case of geoengineering, the descriptive objection still holds. There is no reason to assume that just any kind of geoengineering will produce even universal net benefits (see also 3.4).

3.2 Normative requirement?

A third interpretation is that Barrett concedes the threat to universal benefit, but is proposing that the task of governance is to defeat this threat by creating a situation where universal

[4] Even those who reject the definitional claim often presuppose universal benefit in particular cases, since they typically assume that underprovision is a problem to be solved.

[5] The inference to (d) is misleading. Governance is an issue even with universal benefit (see below).

benefit holds. In other words, the governance regime is charged with *making* the good (in this case geoengineering) a genuine global public good (cf. Barrett 2007, 179). This picks up on the possibility that, while it is most natural to understand the claim that geoengineering is a global public good as a generic descriptive assertion about the kind of good that geoengineering is, one might also interpret it as the *normative* claim that the only kinds of geoengineering that *ought to be considered* as the subject of serious scientific research and public policy are those that (a) benefit everyone, and (b) are nonrival and nonexcludable.[6]

The normative move does not leave everything as it was. First, theoretically, the new requirement constitutes a bold ethical claim that requires serious defense, and the kinds of argument relevant to that defense are those of moral and political philosophy, rather than descriptive economics or international relations, since they concern normative adequacy. Second, in practice, the requirement sharply restricts the domain of legitimate research and policy. For example, universal benefit is a high bar to meet that excludes many possible geoengineering schemes (see below), and considering only nonrival approaches would rule out the possibility of rival interventions accompanied by robust compensation provisions. Since most geoengineering advocates support a broad research agenda, they are unlikely to welcome such sharp restrictions.

The universal benefit requirement is subject to three basic worries. First, it is *empirically dubious* and perhaps even *unsatisfiable* in the real world. On the one hand, the standard that all must benefit from an intervention is extremely demanding even in principle. Paradigm forms of climate engineering, such as SSI, aim to alter the basic climate variables of the planet over very long timeframes, from decades to centuries and even millennia. Indeed, this is their essential rationale. As a result, such interventions affect a huge number of people across the entire planet and on an intergenerational scale, not to mention an enormous nonhuman population. Given this, it is far from clear that the universal benefit standard can be met; indeed, it seems doubtful that any policy or technology has ever been so successful.

On the other hand, early scientific work already suggests plenty of scope for differential impacts, many of which seem likely to be negative. In general, solar radiation management "would certainly lead to significant changes in other climate parameters" (Schmidt et al. 2012), and "has the potential to drive regional climates outside the envelope of greenhouse-gas induced warming, creating 'novel' conditions" (Irvine et al. 2010). More specifically, "strongly changed global mean and regional precipitation can be expected" (Schmidt et al. 2012), and some suggest that SSI might weaken the monsoon to such an extent that India *would be better off facing severe climate change* (Robock et al. 2008).

The second basic worry is that the universal benefit requirement is *ethically unreasonable*. On the one hand, it is *unduly restrictive*. First, it rules out geoengineering that otherwise seems ethically defensible. Consider, for example, interventions that would protect a decent quality of life for all, or ensure that basic human rights could be respected, but at some net cost to the more affluent. Second, it is not clear that it would always be better to satisfy the requirement rather than a less demanding standard even when both are options. For example, an intervention that allowed basic human rights to be protected at a modest net cost to some might be better all things considered than one that provided very small economic benefits (e.g., the equivalent of $1) to all.

On the other hand, the requirement is also *excessively permissive*. For example, Barrett claims that if universal benefit were to hold then it "would not matter" if one state unilaterally supplied a global public good without seeking permission from other states or taking into account their interests (Barrett 2007, 23, 46). However, this is dubious. Take an everyday example. Suppose you break into my house while I am out and, being a compulsive neat freak, clean it up. Suppose I agree that your cleaning benefits me (even though that was not your motivation). Still, it is not true

[6] Interestingly, the first Oxford Principle may be best read in this way.

that I have no complaint, or that overall your actions are justified. You violate my rights. Even though you also benefit me, I have a legitimate, and in this case decisive, objection.

This point is relevant to geoengineering. Suppose a state were to implement SSI successfully without the permission of other states and without consideration of their interests, yet (perhaps miraculously) the intervention benefited everyone. Still, there would be grounds for complaint. Some would involve values other than welfare (e.g. rights, justice). Others might appeal to welfare itself: perhaps the intervention benefits other states, but not as much as some alternative policy. For example, perhaps it ignores long-term benefits, perhaps other interventions would be better even in the short term, or perhaps the overall benefits of respecting rights outweigh the benefits of accepting this intervention. Whether such objections would be decisive or not would depend on the circumstances. However, we ought not to assume that they have no place.

The third basic worry about the universal benefit requirement is that it appears to have the *wrong target*. In context, it seems to function as a constraint on technological interventions considered simply as such. However, universal benefit is a very high bar to set for a *purely technological* intervention. Fine-tuning a planetary-scale intervention into the Earth's physical systems so that absolutely everyone ever affected by it—globally, intergenerationally and perhaps also across species—is benefitted appears an almost unbelievable technical challenge to hand to scientists and engineers. It also seems absurdly demanding as a constraint on scientific research.

What is missing is the social side of intervention. Whatever the normative requirements for geoengineering are, it is unclear why we would insist that they be secured in a purely physical way, through technological interventions in natural systems. Social intervention (e.g., political, legal and economic innovation) may be less costly, less risky and easier to bring about than asking scientists to find technological ways to meet the same goals. In any case, it should at least be considered. The framing of geoengineering *as such* as a global public good obscures this point. The right question to ask is not how a technological intervention considered in isolation may affect the interests of those affected, but rather how the combination of global physical and *social* systems will do so.

Moreover, social intervention may also require innovation. For example, simple compensation models are often invoked: if the Indians would suffer from SSI, but the rest of the world would benefit, then Indians should be compensated. However, such models seems inadequate. On the one hand, even in normal contexts, I am not usually allowed to inflict harm on you provided only that I then offer compensation. I can't, for example, punch you in the face, hand you $100 and expect us to be even. If harms are to be inflicted, normative matters other than welfare—such as rights, justice and political legitimacy—are also important. On the other hand, implementing SSI is far from a normal context. Normative questions are rife about who should do it, why, with what qualifications, and what further obligations. Arguably, in a complex global, intergenerational and ecological setting, we lack robust answers to these questions, even in theory, let alone in the hard world of international relations. Social innovation may well be absolutely necessary.

3.3 Impure public goods

A different strategy for saving the universal benefit requirement is to try to weaken it. This suggestion gains momentum from the observation that genuinely pure public goods are rarely found in the real world, so that in practice policy must address impure public goods. The key questions are then what the weakened requirement should be, whether it escapes the above objections, and whether it remains a reasonable interpretation of 'universal benefit'.

Suggest two standards familiar from public policy analysis the authors of the Oxford Principles as alternative interpretations of the universal benefit claim for geoengineering (Rayner et al. 2013. 8–9). First, the Pareto principle requires that some be made better off and none worse off. This idea is influential in the global public goods literature. The seminal work from the UNDP defines as a minimal condition for an impure global public good that it "benefit more than one group of countries, and not discriminate against any population segment or set of generations" (Kaul et al. 1999, 11). Unfortunately, this principle runs into the earlier objections: it looks empirically dubious and ethically unreasonable. For example, designing a purely technical intervention so that no one (globally and intergenerationally) is made worse off seems a very tall order, and the demand also seems ethically unreasonable (e.g., making the very rich a little worse off but protected the basic human rights of billions may be worth considering).

Second, the Kaldor-Hicks criterion requires that those who benefit from an intervention be able *in principle* to compensate those who suffer. On the surface, this suggests a concern with how benefits are distributed. However, since compensation need not actually occur, the criterion reduces to the claim that the overall benefits of geoengineering must be greater than the costs, regardless of the distribution. Ethically, this is highly controversial. In principle, it justifies the infliction of all manner of costs onto some purely for the benefit of others, regardless of whether compensation is paid and without any discussion of matters such as rights, justice and responsibility. Moreover, in context it is a deeply implausible interpretation of the claim that geoengineering "benefits all", and undermines the thought that no one has an objection to provision.

3.4 Catastrophe baseline?

The above arguments are open to an objection. Some claim that universal benefit is not only achievable, but easily so. The thought is (deceptively) simple: if the alternative to geoengineering is catastrophic climate change, surely everyone will benefit, since everyone will avoid catastrophe. This gives us a new interpretation of universal benefit: to benefit all is to make everyone better off than they would be against the baseline of catastrophe. For example, one of the world's most prominent researchers, Ken Caldeira, states:

> "… for most reasonable climate change metrics, if any party acted in their own self-interest [in implementing SSI] every party would be better off than if no party had acted" (Caldeira 2012)

Hence, in his view universal benefit is (a) technically possible, (b) readily available (in the form of SSI), and (c) can be secured by any party acting in their own self-interest. These claims are compatible with, but go far beyond, the usual public good claim.

One set of worries about the catastrophe argument is empirical. First, we should not forget that the empirical work in this area is in a very early stage, such that model results are likely to provide only very weak foundations for policy judgments, since (with all due respect) the data that informs them is likely to be incomplete and the theory overly simplistic. Most scientists not only acknowledge, but emphasize this point (e.g., Schmidt et al. 2012).

Second, even setting this aside, the claim that universally beneficial geoengineering is technically possible and readily available is empirically contentious. For example, Caldeira supports his position by citing a paper by Kate Ricke, Granger Morgan and Myles Allen. This does assert *in passing* (see later) "our results confirm that solar-radiation management would *generally* lead to less extreme temperature and precipitation anomalies, compared with *unmitigated* greenhouse gas emissions" and "… even at the regional level, such a geoengineered world bears *much closer* resemblance to a low-CO2 world, than either world bears to an *unmodified* high-CO2 world" (Ricke et al. 2010, 537). However, these pairwise

comparisons fall far short of the critical assertion that *all* would be *better off* under SSI. Instead, they suggest only that a sulfate injection world would have some general and *prima facie* advantages over a world with unmitigated climate change. Consider just two difficulties. First, the claims are not about *everyone* in the relevant sense. They are generalizations about overall tendencies, not guarantees for each subject affected. For all that is said, though overall there may be less anomalies under the intervention considered than under severe climate change, some subjects might experience more. Second, the scope of the claims is too limited. Not only do they involve only two variables (temperature and precipitation) when many more are relevant (as the original authors acknowledge), but those considered are broad-brush climate variables, rather than the more specific welfare and ethical variables needed to justify a robust "better off" claim. In short, the claim that SSI benefits everyone appears premature and to involve empirical overreaching.

The catastrophe argument also invites conceptual worries. From a policy point of view, comparing geoengineering with a world in which no climate action at all occurs is problematic in at least four ways. First, the primary comparison should be with the *best* alternative policies available. For example, if aggressive mitigation and adaptation, or indeed other forms of disaster preparedness, are better than either catastrophe or geoengineering, the pairwise comparison loses much of its relevance.[7]

Second, considered against a baseline of true catastrophe almost anything counts as an improvement, so that meeting the requirement becomes too easy, in the sense of *ceasing to be normatively impressive*. "Just a little better than catastrophe" is a very low normative threshold. For one thing, many policies may reach this bar. Given this, the problem of comparing with the best alternatives (above) becomes pressing. Perhaps more importantly, even if only one kind of policy (i.e., SSI) can reach the bar, it is *no longer clear that doing so remains such a compelling policy goal*. For example, making people a tiny bit better off than under a climate Armageddon may (reasonably) be deemed much less important than focusing one's energies on trying to avoid the catastrophe more directly, even if this has low probability of success. More generally, there is the suspicion that, if all that is normatively required is something "better than catastrophe", the result that geoengineering makes things better is achieved almost by definition. One merely needs some reason (however weak) to think that the proposed intervention might be marginally better than catastrophe and a case can be made.

Third, the 'better than catastrophe' threshold tends to *conceal ethically troubling results*. Consider, for example, geoengineering implemented by a severely unjust global totalitarian regime that reduced most of humanity to a situation akin to abject slavery. In principle, this might satisfy the requirement that "every party would be better off than if no party had acted". Yet this says more about how bad climate catastrophe is than the moral desirability of abject slavery. To make only the pairwise comparison risks obscuring much of what at stake in choosing such a world.

This worry reflects the fourth and more general problem: the use of the language of *benefit* against the backdrop of catastrophe is contentious and liable to mislead. For example, although there is a sense in which everyone might be better off under slavery than true catastrophe, the claim that slavery therefore "benefits all" is deceptive. This is especially so given that much of the point of the universal benefit claim is to diffuse objections. In the slavery case, we are unlikely to be misled by such a linguistic trick; in the case of geoengineering, the risk is much higher (Gardiner 2011, chapters 9–10).

These empirical and conceptual worries do not imply that geoengineering cannot be justified, or that either the Ricke results or the prospect of catastrophe are irrelevant to justification. What

[7] Many geoengineering advocates argue that better policies have proven politically unavailable. This is an independent argument, which should be assessed on its merits, not obscured by the pairwise approach.

they do suggest is that justification requires identifying and meeting more sophisticated ethical requirements. Unfortunately, the catastrophe argument tends to obscure these vital tasks.

3.5 Beyond universal benefit

In conclusion, there are strong objections to the claim that geoengineering benefits all. The generic descriptive version is false. The normative version seems empirically dubious, ethically unreasonable, and to have the wrong target. Attempts to weaken the claim through appeals to Pareto, Kaldor-Hicks, and a benchmark of climate catastrophe are unconvincing and tend to obscure much of what is at stake. In general, geoengineering strays far from the lighthouse paradigm. This makes it misleading to present it as a global public good in the broad sense.

In my view, much of the theoretical integrity and interest of the term 'global public good' turns on preserving some form of benefit claim (see below). However, some wish to excise all normativity from the definition of 'global public good' by stipulating that 'good' should be understood in a normatively neutral way, as referring simply to a commodity or policy as such, whether normatively good or bad (Bodansky 2012). For them, nonrivalness and nonexclusivity are the sole defining features of a public good. This narrow account radically extends what can be called a 'global public good'. It allows for both the universally harmful (proponents of the broad account call these 'global public bads'), and for goods with normatively divergent implications for different actors. From now on, we shall focus on such "global mixed bags", as a way of seeing how the narrow account of global public goods is also ethically misleading for geoengineering.

4 Nonrival?

A purely rival good is one whose consumption by one agent precludes consumption by another. A paradigm example is a specific ice cream: if I eat it, you cannot. By contrast, a purely nonrival good is such that one agent's consumption does not inhibit another's. In the lighthouse case, the fact that I can see the rocks does not inhibit your ability to do so. Usually, nonrivalness is assumed to be a good thing. In paradigm cases involving universal benefit, it means that when some provide the good for themselves, opportunities to benefit become available to others at no extra cost; hence, there is reason to encourage provision, or at least not to prevent it.

In my view, 'nonrivalness' is best understood as an umbrella term, covering a number of possibilities. For example, for one thing, nonrivalness can be understood in a restricted or an expansive sense. In the restricted sense, it means that one agent's consumption of a particular good does not inhibit any other agent's consumption *of that same good* (Stern 2007, 27). More expansively, it can mean that one agent's consumption of the good has no effects on other agents more generally (Bodansky 2012, 4). In addition, what counts as "one agent's consumption not inhibiting another" is underdetermined, and likely to depend in part on how we describe the good in question.

In the case of SSI, I shall identify three central possibilities, and argue that each is unhelpful for the global public good analysis. Consider first two salient ways in which SSI *as such* is not nonrival. On the expansive reading, the consumption of one agent clearly can have negative implications for others. For example, SSI at a certain level may be good for the US, but bad for India and its monsoon. On the restricted reading, one agent's consumption of SSI can inhibit another agent's consumption of SSI. For instance, if the US prefers a substantial amount of SSI, whereas Russia prefers a modest amount and India none at all, then the US's consumption at its preferred amount *precludes* Russia's and India's consumption at theirs (and *vice versa*).

Recognizing both forms of rivalness is important to understanding the ethical challenges of geoengineering. First, geopolitically, expansively rival interventions may be selected, and sometimes precisely because they are rival. At the extremes, there are risks of predatory geoengineering (targeted against some particular group, such as an economic or military adversary), and parochial geoengineering (preferred because it provides benefits to the current generation while passing the costs on to later generations). Hiding such possibilities behind the assumption of nonrivalness assumes away some of the most serious ethical risks of geoengineering (Gardiner 2011).

Second, choices *between* interventions are highly likely to be rival in the restricted sense *even if generally beneficial interventions can be found*. Those contemplating deployment must compare (perhaps countlessly) many kinds and levels of intervention, such as SSI to cap global temperature rise at 2° or 1.5°, direct air capture to remove 50 or 150 ppm of carbon dioxide, and so on. Each is likely to have different effects, resulting in distinct positive and negative impacts on particular populations. Given this, different actors will assess the options differently, so that the choice of specific intervention is rival. Moreover, presumably, no one wants a world in which several different countries tries to implement SSI to achieve different targets (e.g., Russia aiming at 2.4°, China at 1.5), since this sounds both self-defeating and highly dangerous. Consequently, the selection of a particular SSI scheme does in effect preclude other choices, so that one group's concerns may be completely excluded by the choice of a particular scheme. For example, a powerful country intent on SSI may be unmoved by the plight of sub-Saharan Africa, or the interests of future generations. One consequence is that we should worry about preemptive geoengineering (aimed at precluding the (rival) consumption of others).

To illustrate, consider again the Ricke paper. Its main theme is that at the regional level average temperature and precipitation come apart, and that this gets worse the longer SSI continues. Hence, it concludes: "it may *not be possible* to *stabilize the climate in all regions simultaneously* using solar-radiation management [SRM]", because what count as *"'optimal' SRM activities imply different things for different regions"*. Moreover, it observes that this has negative implications for action: "regional diversity in the response to different levels of solar-radiation management could make consensus about the optimal level of geoengineering *difficult, if not impossible*, to achieve" in part because "serious issues of *regionally diverse impacts and inter-regional equity* may further complicate what is already a very challenging problem in risk management and governance" (Ricke et al. 2010, 537). In other words, the paper suggests that, even if overall some forms of SSI would benefit everyone, any actual deployment is likely to imply hard choices that are politically and ethically contentious.

SSI is perhaps nonrival in a third sense. Once a specific intervention is provided, all "consume" the effects without prejudice to others doing the same: the effects are not the sort of thing that can be "used up" by some. Superficially, this can seem like the lighthouse case: once the lighthouse is there, one sailor's experience of the light does not inhibit others experiencing it. Unfortunately, this sense is deflationary in a way that is misleading and risks redundancy.

First, divorced from the context of universal benefit, it lacks the usual implications. In paradigm cases where benefits are supplied to all, nonrivalness is assumed to be a reason to encourage or at least permit provision. By contrast, knowing that an intervention that benefits some and harms others (a "mixed bag") is nonrival in the deflationary sense tells us little about how to address it. Instead, further and distinctively ethical analysis is needed.

Second, the deflationary sense risks eviscerating the concept of the nonrival in the definition of a public good. It is very close to the claim that, once the specific intervention is provided, no one can be prevented from experiencing the effects. But this is just the claim of nonexcludability. Hence, insisting on this sense risks denying nonrivalness any independent status, and so undermines the traditional distinction.

In conclusion, climate engineering is rival in two important senses. Geopolitical competition suggests threats of expansively rival interventions, and choices between competing schemes are highly likely to be restrictedly rival. Rather than the rosy picture whereby "one's consumption does not inhibit another's", SSI involves serious distributive issues, which are likely to set agents at odds. Given this, ethical concerns, and especially those of justice, are central and unavoidable.

5 Nonexcludable?

Technically, a good is nonexcludable if "once it is available to some, others cannot be prevented from consuming it". Traditionally, in cases such as the lighthouse, the focus of economic analysis is on the position of the *provider* of the good. Since lighthouse builders cannot prevent others from using the light, they are vulnerable to free riding; hence, the worry about underprovision. SSI is nonexcludable in this sense: A's deployment would have global effects, and it could not prevent B from experiencing those effects even if B refused to contribute to the costs of provision. Nevertheless, the implications are different than in the lighthouse paradigm. In particular, neither underprovision nor the unfairness of free riding are central concerns. On the one hand, SSI is usually said to be relatively cheap to deploy, such that *unilateral provision* by a rogue nation is often presented as the most serious threat.[8] On the other, in my view free riding is less of a concern than competitive provision: the threats of predatory, parochial and preemptive SSI, and of geopolitical conflict.

An alternative way to approach the technical definition is to consider the position of nonproviders (Bodansky 2012, 22). Nonproviders cannot "exclude" themselves from consuming: benefits or costs can be imposed on them whether they want them or not. This is highly relevant to SSI, since it alters climate everywhere, and nonproviders are vulnerable to whatever providers do.

Unfortunately, this approach is liable to mislead. In general, the vulnerability of nonproviders is really an ethical issue, most properly confronted with concepts such as rights, justice, political legitimacy and virtue. Hence, to insist that it justifies framing geoengineering as a global public good is seriously misleading and encourages the background worry that 'global public good' has become "a *catch-all* to which people can attach anything they want" (Carbone 2007, 185).[9]

More specifically, the implications are different than in the lighthouse case. First, with lighthouse provision it is reasonable to assume that what nonproviders are not excluded from is a genuine benefit, but with SSI there is a serious risk that what nonproviders "cannot be prevented from consuming" is the infliction of serious costs or harms on them by others. Again, issues of justice, rights and political legitimacy come to the fore.

Second, with SSI, some kinds of exclusion are possible, and some may be able to "exclude" themselves more than others. For one thing, providers might select interventions that disproportionately supply them with positive effects while sending negative ones elsewhere. For another, some may be better placed to defend themselves against negative effects (e.g., through location, existing infrastructure, or general affluence). For instance, if SSI enhances drought in some areas, those wealthy enough to import food and water may be able to protect themselves better against the immediate impacts. Importantly, in both cases, one morally relevant feature of the paradigm example—the sense of sharing in the same fate—is diminished. Compared to the lighthouse, the so-called "public good" is no longer uniformly good, nor uniformly public.

[8] For more expensive technologies, such as air capture, underprovision may be a serious issue.

[9] The third UNDP volume strays in this direction by not only dropping the universal benefit claim, but also defining a public good as *either* nonrival *or not excluded* (Kaul and Conceicao 2006).

In conclusion, though geoengineering is relevantly nonexcludable, the implications are not those of the usual public good analysis and differ from the lighthouse paradigm. Again, the neglect of the ethical dimensions is central.

6 Justice and the relevant public

Two more general worries arise about the public good framing. First, from an ethical point of view, the relevant public is global, intergenerational and ecological. However, it is far from clear that the conventional framings have this in mind. In particular, Barrett's general account relies on states to pursue "their own interests" in securing global public goods, and Caldeira claims that any agent's pursuit of its own interests in geoengineering will promote universal benefit.[10] Moreover, neither explains why we should expect nation states as currently organized to take the ethical ideal seriously. This is a serious defect if the temptation to pass costs and harms onto other nations, the future and nonhuman nature is a central driver of the climate crisis. If, for instance, what passes for "self-interest" actually reflects only the short-term and narrowly economic goals of a few specific groups in particular powerful countries, then their sense of "public good" seems likely to perpetuate "shadow solutions" that appear on the surface to be real action but are actually further manifestations of the underlying problem (Gardiner 2011).

Second, the public good framing arbitrarily excludes other morally-relevant dimensions of the climate issue. For instance, arguably, rather than being described as the *supply of a universal benefit,* ethical geoengineering might be better seen as an attempt at *rectifying injustice*. This shift makes a substantial difference. For instance, the 'supply of a universal benefit' framing is exclusively forward-looking, and so covertly ignores issues of prior responsibility, whereas the 'rectifying injustice' framing highlights them. Making such a move through definitional fiat is likely to hamper the prospects for ethical geoengineering, especially if the main geoengineering advocates are those primarily responsible for generating the climate threat (e.g., through high emissions and resistance to mitigation).

7 Concluding Remarks

Early policy work often frames geoengineering as a global public good. However, stratospheric sulfate injection fits neither the canonical definition nor the paradigm (lighthouse) example. SSI is not universally beneficial, and is importantly rival. Though it is nonexcludable, this does not have the standard implications. Moreover, the rosy picture for public policy normally suggested by the public good framing is seriously misleading. Rather than underprovision, the main threats are of competitive, predatory, parochial, and other unethical forms of provision. Rather than provision being unambiguously welcome, nonproviders may have strong and legitimate grounds for complaint. Instead of widespread cooperation being unnecessary, ethical geoengineering probably requires it, since justice is a central issue. Finally, the prospect of some states coercively imposing SSI remains seriously controversial. Rather than a seemingly benign supply of a universal benefit, implementation of SSI looks more like the exertion of monopoly power. Since this is power over the basic ecological circumstances of the planet, affecting the life prospects of all concerned, geoengineering raises very serious, indeed

[10] The original statement of the first Oxford Principle was ambiguous (as noted by the UK government). Subsequently, the authors clarified that they intend at least the global and intergenerational concerns (Rayner et al. 2013).

foundational, questions about political legitimacy, justice and humanity's relationship with the rest of nature. The need to discuss such matters should not be obscured behind the rosy façade of a misleading and unhelpful technical term.

Acknowledgements The author is grateful for research support from the Environment Institute of the University of Washington College of the Environment, the Smith School for Energy and the Environment at Oxford University, the Netherlands Institute for Advanced Study in the Humanities and Social Sciences (NIAS), and the Center for Biological Futures (Prime Contract No. HHM 402-11-D-0017) at the University of Washington. He also thanks Simon Caney, Ben Gardiner, Lauren Hartzell Nichols, Clare Heyward, Dale Jamieson, Julian Savulescu, Henry Shue and two anonymous reviewers for their comments. The views expressed remain solely the responsibility of the author.

References

Barrett S (2007) Why cooperate? The incentive to supply global public goods. Oxford

Bodansky D (2012) 'What's in a concept? Global public goods, international law, and legitimacy' 23. Eur J Int Law

Caldeira K (2012) Ethics of geoengineering (Food). Geoengineering Google group. April 12

Carbone M (2007) Supporting or resisting global public goods? Glob Gov 13:179–198

Gardiner SM (2011) A perfect moral storm. Oxford

Irvine PJ, Ridgwell A, Lunt DJ (2010) Assessing the regional disparities in geoengineering impacts. Geophys Res Lett 37

Kaul I, Grunberg I, Stern MA (eds) (1999) Global public goods. Oxford

Kaul I, Conceicao P (eds) (2006) The new public finance. Oxford

Keith D (2000) Geoengineering: history and prospect. Annu Rev Energy Environ 25:245–284

MacCracken M et al (2010) The Asilomar conference on principles for research into climate engineering techniques. Climate Institute, Washington DC

Nature (2012) A charter for geoengineering. Nature 485:415, Editorial

Rayner S (2011) The challenges of geoengineering governance. In: RSIS Centre for Non-Traditional Security (NTS) studies, Pilot Workshop on Governing Geoengineering in the 21st Century: Asian Perspectives. Singapore. pp 10–11

Rayner S, Redgwell C, Savulescu J, Pidgeon N, Kruger T (2009) Memorandum on draft principles for the conduct of geoengineering research. Available at http://www.geoengineering.ox.ac.uk/oxford-principles/history/

Rayner S, Redgwell C, Savulescu J, Pidgeon N, Kruger T (2013) The Oxford principles. Clim Chang

Ricke K, Granger Morgan M, Allen M (2010) Regional climate response to solar-radiation management. Nat Geosci 3:537–541

Robock A, Oman L, Stenchikov GL (2008) Regional climate responses to geoengineering with tropical and Arctic SO2 injections. J Geophys Res 113:D16101

Schmidt H et al (2012) Solar irradiance reduction to counteract radiative forcing from a quadrupling of CO_2. Earth Syst Dyn 3:63–78

Shepherd J et al (2009) Geoengineering the climate: Science, governance and uncertainty. Royal Society

Stern N (2007) The economics of climate change: the stern review. Cambridge

Stiglitz J (2000) Economics of the public sector. Norton

UK Government (2010) Government response to the House of Commons Science and Technology Committee 5th report of session 2009–10: the regulation of geoengineering. The Stationary Office, London