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Geoengineering: neither economical, nor ethical—a risk–reward nexus analysis of carbon dioxide removal

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Abstract This article addresses a central debate in combatting climate change: whether we should focus on reducing CO_2 emissions or on removing the emitted CO_2 from the atmosphere. We favor the former by arguing against the economic viability of the carbon dioxide removal (CDR) branch of geoengineering. This is of course not a question of either or, but we argue that the perception of CDR as a viable option reduces the willingness to reduce CO_2 emissions. Using the recently developed approach of risk–reward nexus (RRN) in the economics of innovation, we question the economic viability of CDR. The main argument is simple: if one uses the new framework of RRN in evaluating the innovations involved in the CDR branch of geoengineering, not only does one include more areas of risk but also one has to consider a broader base for distributing the rewards. Consequently, from RRN's point of view, it would be less likely to find investing in CDR economically viable for the investor firms. Although the core argument of the paper concerns the economics of CDR, in a final section the paper tries to show that the economic argument has also ethical implications against relying on CDR.

Keywords Economics of geoengineering · Carbon dioxide removal · Risk-reward nexus · Justice and economics · Hegelian ethics

Abbreviations

BECCS	Bio-energy combined with carbon capture and storage
CBA	Cost benefit analysis
CCS	Carbon capture and storage
CDR	Carbon dioxide removal
CO_2	Carbon dioxide
IPCC	Intergovernmental panel on climate change
OECD	Organization of economic cooperation and development

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PNAS	Proceedings of the national academy of sciences
RRN	Risk–reward nexus
SRM	Solar radiation management
UNFCCC	United nations framework convention on climate change

1 Introduction

The idea of geoengineering to modify the climate has been around for decades (Buck 2012). The Paris Agreement, by setting the aim of limiting the temperature increase to 2° or even 1.5 °C in this century compared to pre-industrial levels, may have unwittingly given an impetus to the carbon removal option; that is to say the "negative emission" technologies. The vast majority of mitigation scenarios now include massive deployment of negative emission technologies, notably bio-energy combined with carbon capture and storage (BECCS) (Clark and Herzog 2014; Mander et al. 2017; Rogelj et al. 2015; Schleussner et al. 2016). As Anderson (2015a, b) has convincingly demonstrated, the only plausible assumption behind the overwhelming majority of 2 °C mitigation scenarios depicted by the intergovernmental panel on climate change (IPCC) is, to Anderson's dismay, the reliance on large-scale removal of CO_2 from the atmosphere. Combined with the insufficient mitigation commitments by countries (Rogelj et al. 2016), this makes the use of some form of geoengineering seem inevitable. Although other forms of geoengineering are increasingly discussed as deployable options as a result of the Paris Agreement (Horton et al. 2016), our discussion is limited to CDR and related technologies. Throughout the paper, we interpret carbon dioxide removal broadly, to encompass all methods of carbon capture storage (CCS), including BECCS. It is important to note that CCS in and of itself cannot achieve negative emissions, only when combined with combustion of bio-energy (BECCS). Carbon capture technologies can remove 80–95% of the CO_2 from combustion but at a loss of energy output of about 25% (International Energy Agency 2014) which means that the entire process is less efficient than often assumed and is also associated with a range of other concerns, such as leakage and permanence of the sequestered CO_2 (Leung et al. 2014).

CDR has in recent years been promoted by many influential actors including the (then) IPCC Chairman Rajendra Pachauri (Pagnamenta 2009), the (then) Executive Director of UNFCCC Christiana Figures (Harvey 2011), the Worldwatch Institute (2009), and the OECD (2012). A recent opinion piece in PNAS also concludes that BECCS is one of the most viable and cost-effective negative emission technologies (Venton 2016). But what brought the CDR branch of geoengineering into the mainstream strategies of combatting climate change was perhaps the prestigious Royal Society Report of 2009, which declared CDR a viable option in dealing with climate change (Shepherd 2009).

In this paper, we argue against the carbon dioxide removal (CDR) branch of geoengineering (and, by extension, against the related technologies indispensable for CDR). As will be elaborated below, using the recently developed approach of risk–reward nexus (RRN) in economics of innovation, it is the economic viability of CDR that we question. Our argument is simple: if one uses the new framework of RRN in evaluating the innovations involved in the CDR branch of geoengineering, not only does one include more areas of risk, but also one has to consider a broader base for distributing the rewards.

Consequently, CDR is less economically viable for investor firms if one applies the RRN framework.

In the short Sect. 2, we demonstrate how the commercial application of CDR encourages continuing reliance on fossil fuel. In Sect. 3, we briefly review the existing arguments against geoengineering. Our main argument against the economic viability of CDR is elaborated in the longer Sect. 4. In a final section, we discuss the ethical implication of our economic critique from the vantage point of Hegelian ethics.

2 Viability of CDR and its impact on fossil fuel

The mainstreaming of carbon removal has immediate implications for other strategies of tackling climate change, notably a negative implication for the mitigation of CO_2 emissions by substituting renewable energy for fossil fuel. The possibility of removing CO_2 from the atmosphere will illusionarily allow governments, at least in theory, to meet the targets of the Paris Agreement while fossil fuel continues to be the main source of energy production. Indeed, the International Energy Agency report of 2016 on World Energy Outlook clearly states the same thing:

> For the moment, the collective signal sent by governments in their climate pledge (and therefore reflected in our main scenario) is that fossil fuels, in particular natural gas and oil, will continue to be a bedrock of the global energy system for many decades to come (International Energy Agency 2015, p. 5).

The report projects that the supply of fossil fuels on the world market will continue to grow at least until 2040. To be sure, the report maintains that the efficiency of fossil fuel consumption must improve in order for governments to meet the Paris Agreement targets, but relying on CCS is a natural corollary of the continued reliance on fossil fuel. For instance, in the case of coal,

> [a]longside the measures to increase coal-plant efficiency and reduce pollutant emissions, the long-term future of coal is increasingly tied to the commercial availability of carbon capture and storage (Ibid, p. 10).

Indeed, it has been argued that carbon capture and storage, far from incurring any costs on burning fossil fuel, should be regarded by the fossil fuel industry "as a potential enabler of utilizing otherwise stranded fossil fuels[1]" (Clark and Herzog 2014). Here is a telling example: "… we estimate that a total of approximately 5400 EJ of coal and 3500 EJ of natural gas can be rescued by CCS over this time period (2010–2100). This inclusion of coal- and gas-fired electricity with CCS also rescues oil assets amounting to 2400 EJ from 2010–2100. This… shows that CCS [could increase] fossil fuel utilization close to a 70% with no increase in CO_2 emissions." (Clark and Herzog 2014, p. 7269). One could even infer that it is not simply the threat of climate change but these untapped fossil fuel assets that have incentivized the deployment of carbon capture and storage (Clark 2015).

Whatever the direction of causality, the link between carbon removal and continued use of fossil fuel is easy to see. The support for CDR from the fossil fuel industry (e.g., the Global CCS Institute: http://www.globalccsinstitute.com/) is to balance the "remaining

[1] By 'stranded fossil fuel,' they (Clark and Herzog 2014) mean the coal, oil and natural gas that need to be left in the ground (almost one third of current known global carbon reserves) if Paris's 2 °C target is to be met.

sources of emissions" (Hone 2016), i.e., profits, from fossil fuels. The former U.S. Secretary of Energy was explicit when commissioning the report "Fossil Forward" that CCS is "critical to the future of fossil fuels, particularly coal, used in this country" (National Coal Council 2015).

Many governments are continuing their support for the fossil fuel industry (Edenhofer 2015). The subsidies for the consumption of fossil fuel worldwide amounted to half a trillion dollars in 2014. It is true that this figure fell nearly by third, to $325b, in 2015; but this was due solely to the sharp fall in fossil fuel prices (International Energy Agency 2015, p. 1) and was not the result of the reduction by Governments of subsidies.

With continued reliance on fossil fuel, CDR is the only way open to governments if they are serious in fulfilling their pledge in the Paris Agreement. It sometimes seems that even the Royal Society Report regards CDR as a way of coping with the continued fossil fuel emission: "The current CO_2 release rate from fossil fuel burning alone is 8.5 GtC/year, so to have an impact CDR interventions would need to involve large-scale activities (several GtC/year) maintained over decades and more probably centuries" (Shepherd 2009, pp. 9–10). No wonder the environmentalists who were initially cautiously optimistic about the Paris Agreement (Monbiot 2015) are now alarmed that their governments may be opting for CDR to meet the Paris Agreement targets (Monbiot 2016).

3 The case against geoengineering

There have been a host of objections to climate engineering but the economics, to our knowledge, have rarely been central to the objections. The notable exceptions are Goes et al. (2011), which models the economics of aerosol geoengineering and finds it economically *not* viable; and the important paper by Klepper and Rickels (2012) which we will come back to in the next section.

The noneconomic objections to geoengineering, on the other hand, abound. To begin with, geoengineering, like all purely technical solutions, is open to the criticism that it ignores the power relations that inevitably go hand in hand with any particular technology (Baskin 2015). At a purely technical level, not only is the precautionary principle thrown to the wind, but even in the case of a less radical technology, like bio-energy with carbon capture and storage (BECCS), it is maintained that there are several areas in which our knowledge is simply inadequate to warrant the use of such technology (Fuss et al. 2014). The same is true of iron fertilization of oceans to sequester more CO_2 (Powell 2008). Furthermore, the legal aspect of iron fertilization of oceans is so problematic that the experts believe that it is not a feasible way of climate engineering (Abate and Greenlee 2009). The legal issues involved in geoengineering readily give rise to all sorts of complex ethical, even philosophical, considerations: the question is not only *how* we decide on the use of particular forms of climate engineering, but *who* decides (Burns and Strauss 2013, p. 2; Barrett 2008)? The complexities involved in the process of decision making, far from being purely technical matters in designing a governance arrangement (Humphreys 2011), have immense social implications at the global level. For instance, it has been persuasively argued that BECCS may easily open the way to land grab on a global scale (Moreno et al. 2016, p. 42).

All these considerations constitute good grounds for skepticism toward geoengineering. As advocates of renewable energy and other forms of mitigation have frequently argued, there is enormous moral hazard involved in opting for climate engineering, acknowledged by the very same Royal Society Report (Moreno et al. 2016; Shepherd 2009). Setting foot on the pathway of climate engineering will almost certainly reduce the effort and resources invested in exploring other alternatives. Yet there is also the economic aspect of geoengineering; and we believe it is the first and foremost reason why geoengineering, at least in its CDR branch, has gained such a prominent place in combatting climate change.

4 Is CDR economically viable?

The landmark report of the Royal Society does not regard geoengineering as *the* solution to climate change, but stresses the primary role of mitigation and adaptation. Geoengineering is only an addition to the portfolio of methods tackling climate change: "Geoengineering methods could, however, potentially be useful in future to augment continuing efforts to mitigate climate change by reducing emissions." Accordingly, the report is very thorough in evaluating different forms of geoengineering separately. In the case of CDR methods, it differentiates between "Land-based CDR methods" and "Ocean ecosystem methods," and it comes to the conclusion that, "the methods proposed differ in terms of the scale of reductions possible, their environmental impacts and risk of unintended consequences, and cost." The report acknowledges that "[s]ignificant research is, however, required before any of these methods could be deployed at a commercial scale," yet the final conclusion is unmistakable:

> If applied at a large enough scale and for long enough, CDR methods could enable reductions of atmospheric CO_2… In principle similar methods could also be developed for the removal of non- CO_2 gases from the atmosphere. (Shepherd 2009, p. 21).

That conclusion presupposes not only the technical viability but equally the economic viability of some CDR methods. It is only on the assumption of economic viability that the report can claim that the remaining problem involves "serious and complex governance issues which need to be resolved if geoengineering is ever to become an acceptable method for moderating climate change." (Shepherd 2009, p. ix)

Economic viability means only one thing: the market forces of supply and demand, through the given institutional setting, will ensure that the necessary investment funds will go to this branch. In other words, compared to existing investment opportunities, investment in climate engineering would be profitable for private business. But how do we know that this is really the case?

To answer this question, one has to consider how firms decide where to invest. Usually, it is a matter of simple comparison of different investment opportunities. Provided that there is enough information about the costs and benefits of each opportunity, a simple cost–benefit analysis (CBA) would determine which one is more desirable. The CBA method has also been used to determine the economic viability of geoengineering at least as early as 2000 (Barrett 2008), and is still common in the debate about the economic viability of geoengineering (Bickel and Agrawal 2013). Below we discuss at some length why we believe CBA is not the appropriate method to investigate the economic viability of climate engineering. However, it is important to draw attention to the important work by Klepper and Rickels (2012) who have detailed the shortcomings of the CBA calculation for both the CDR and the solar radiation management (SRM) branches of climate engineering. The authors make it clear that they believe economic considerations should not be the only criteria for deciding between different strategies of tackling climate change, but for our purpose here the point must be stressed that they have convincingly shown how the prices used in cost–benefit analyses of such projects are not reliable at all. While the conclusion of our argument is wholly in line with that of Klepper and Rickels', we question the very use of the CBA method in deciding the viability of geoengineering projects.

Relying on cost–benefit analysis is basically what all firms usually do for investment decision making, but when it comes to the instances of *innovation,* things are not that simple. "Innovation," almost by definition, involves entering into uncertainties with unknown costs and equally unknown benefits. Uncertainty is distinguished from risk in the literature by the simple fact that while risk is calculable (quantifiable), uncertainty by definition does not lend itself to quantifiable calculation. This is obviously true, but the fact that the outcome of innovations is uncertain does not exclude the category of risk; rather, it implies only that the risk is not quantifiable. That is why recourse to CBA is not meaningful here, because we are in the realm of unquantifiable risk taking. Under uncertainty, possible rewards must be proportional to the unquantifiable risks taken, which in plain language means very high rates of return.

4.1 Innovation and risk

Before discussing the economics of risk–reward in some detail, it may be useful to say a few words about innovation. To begin with, *innovation*, as Joseph Schumpeter, the founder of what we may today call "innovation economics" understood the term, is conceptually distinct from *invention* or *technological change* in that innovation entails a *discontinuity* in the economy (Schumpeter 1928). The reminder is necessary, since the proponents of geoengineering often advance the argument that the technologies involved in many branches of climate engineering are not radical at all, but are actually quite simple (e.g., ocean fertilization). Technological change is a constant feature of the market economy, and usually poses no difficulty for neoclassical economics which rests on the assumption of market equilibrium. Schumpeterian innovation, which may or may not involve technological change, is conceptually different in that it *causes* discontinuity in the market.

To be sure, there is much more to innovation (Lazonick 2013), but for our purpose here this simple distinction goes a long way. Taking note of the discontinuity in the market immediately implies that one has to reckon with the fact that the information about prices, i.e., the costs and the benefits, cannot be known by extrapolation of the current state of the economy. For Schumpeter, it is in the nature of things that attempts at innovation might well fail. That is why he identified the agents of innovation, be it individual or corporate, with the spirit of *entrepreneurship* and risk taking.

Keeping Schumpeterian concepts of innovation and risk in mind, it is not difficult to see that even if carbon capture and storage (CCS) is a mature technology and the storage volumes adequate for storing a substantial amount of captured CO_2 (Mac Dowell et al. 2017), there are many practical, political and economic issues that make CCS a risky venture (Gaede and Meadowcroft 2016). The most risky aspect of BECCS, however, is not the CCS part but the bio-energy (BE) part where the production of bio-energy feedstock may seriously interfere with land and water use (Fajardy and Mac Dowell 2017; Smith et al. 2016).

4.2 Why CDR is not economically viable

It is an interesting fact that the Royal Society Report is reluctant to commit fully to its estimation of the risks and costs of CDR:

> All the proposals considered are in the early outline/concept stage and estimates of cost and environmental impacts are very tentative. However, an initial evaluation is possible using criteria developed for the purposes of the report… (Shepherd 2009, p. 6)

The report's discussion section of CDR puts it squarely:

> On the basis of the available literature… [the discussion is] intended only to show the approximate potential of these technologies if deployed to the maximum, regardless of costs or possible side effects… Costs are assessed as 'low' if generally less than $20 per tonne of carbon sequestered, medium if between $20 and $80, otherwise 'high'. (Shepherd 2009, p. 19)

When it comes to the calculation of the risks, the report is even vaguer:

> Risk is assessed as high for those technologies that involve manipulating the ocean or relatively undisturbed natural land ecosystems at a large scale, and medium for agricultural and biomass technologies, on the rationale that agricultural impacts are relatively well understood and would not directly affect undisturbed terrestrial ecosystems. (Shepherd 2009, p. 19)

The report does not specify what the risks involved are (for a more sophisticated account of the types of risks involved, see (Dooley and Kartha 2017) in this issue). Moreover, there is no quantification of the risks or costs. Consequently, the judgment on the economic viability of CRD hinges solely on setting the right price per unit of carbon removal:

> Plans to begin removal using some methodologies are in place now, and if societies put a realistic value on carbon removal (for example, more than $30 per tonne of carbon), it would start to happen with existing technologies." (Shepherd 2009, p. 19)

What are we to make of the Report's treatment of risks and rewards? A very charitable interpretation would be to assume that the report relies on the literature that has not only taken into account the direct benefits of such ventures to the investors, but has also taken all the externalities (that is the negative consequences that accrue to other institutions and actors other than the investors) into account. One could equally assume that, as is the usual practice with economists, the literature on which the report relies has successfully managed to assign a plausible price to all those externalities that have no market price (say environmental and/or social negative consequences), and has still found the venture economically viable. In other words, let us assume that the calculation on the "cost" side is quite unproblematic. But what about the rewards? Accordingly, in what follows, where we introduce the approach of the new framework of risk–reward nexus, we will focus on the distribution of the rewards of innovation.

4.3 Risk–reward nexus

The case of climate engineering is a classic case of Schumpeterian innovation; not because the technology involved is necessarily radical, but because of the sheer size and scale of the technical operation, because of the hidden linkages that it may in time show to have with other sectors of the economy, and equally because of the unknown impacts it may prove to have on the environment and subsequently on the whole economy. In such cases, one cannot speak of "economic viability" in the conventional sense that applying the method of cost–benefit analysis, carried out by businesses to decide between alternative investment opportunities, may reveal. It is more meaningful to speak of the *prospects* of profitability for such ventures, which like any true venture involves taking big risks in the hope of unusually high profits. Given the magnitude of the risk, it is the unknown magnitude of the probable reward that determines whether the venture would be economically viable.

In the case of climate engineering, one has to look into the economics of the risk–reward. The economic estimate of the risk involved is fairly straightforward and is directly proportional to the immense size of the investment needed for projects on such a huge scale. The reward side is of course problematic and takes us into the realm of economic theory. Broadly speaking, there are two views on the economics of innovation. The "traditionalist" view maintains that all the rewards should go to the shareholders of the firm introducing the innovation. This view is the dominant view in mainstream economics and is backed up by the neoclassical economics of market economy. The revisionist view, labeled risk–reward nexus (RRN), has emerged only recently (Lazonick and Mazzucato 2013). From the RRN perspective, unlike the traditionalist view, it is not only the shareholders of the firm introducing the innovation who are entitled to a share of the reward. It is exactly this tenet of RNN approach which is relevant to our investigation of the economics of geoengineering, but for reasons that will shortly become clear, it is useful to explore briefly the larger context of RRN in the recent developments within the discipline of economics.

In the aftermath of the Great Recession of 2007, unforeseen by the mainstream economists, the neoclassical hegemony in the discipline of economics is seriously challenged, and some very prominent economists have been calling for a new understanding of the dynamics of the present economic system and cycles of growth and recession (Stiglitz 2010), (see also Institute for New Economic Thinking, www.ineteconomics.org). Similarly, with the publication of Thomas Piketty's Capital in the twenty-first century (Piketty 2014), coming on the heels of the Occupy Wall Street movement, the question of gross inequalities in income and wealth redoubled the call for a different approach in the discipline of economics that could better understand the nature of both economic growth and distribution. The contribution of William Lazonick and Mariana Mazzucato must be understood in this context.

Starting from Schumpeter's account of innovation as the engine of capitalist growth, Lazonick and Mazzucato challenge the preoccupation of neoclassical economics with market equilibrium (Lazonick 2013). Instead of the market mechanism, they argue that the innovative enterprise must be the focus of economic theorizing, because both economic growth and distribution of the income depend on the investment strategies and organizational structure of innovative firms. "[W]e need a theory of innovative enterprise that can explain both the creation of value and its distribution among participants in the firm" (Lazonick and Mazzucato 2013). In this new theoretical framework, innovation is characterized not only by *uncertainty*, but equally by being *cumulative* and *collective*.

For Lazonick and Mazzucato, the cumulative nature of innovation does not at all imply a linear model, but a learning process of complex interaction between experiment, market, technology science, government, financial sector etc., with all sorts of feedback loops. Directly relevant to our discussion here is the *collective* nature of innovation. Innovation is a *collective* endeavor because,

> the development and utilization of productive resources is an organizational process that involves the integration of the skills and efforts of people with different hierarchical responsibilities and functional specialties through a network of institutions and relationships (Lazonick and Mazzucato 2013, p. 1095).

Keeping these three aspects of innovation together, Lazonick and Mazzucato set out to analyze "who contributes labor and capital to the process and who reaps the financial rewards from it." This is not the place to go into their analysis step by step. Suffice it to say, once one recognizes the collective nature of innovation, it follows that the entrepreneurs or shareholders are not the only risk takers:

> For high fixed cost investment in physical infrastructures and knowledge bases that have the character of public goods, it is generally the government (representing the collectivity taxpayers) that must engage in this strategic confrontation with uncertainty (Lazonick and Mazzucato 2013, p. 1098).

The role of the state in the information and communication revolution has been extensively documented by Mazzucato. "All the technologies which make the iPhone 'smart' are also state-funded… the internet, wireless networks, the global positioning system, microelectronics, touchscreen displays and the latest voice-activated SIRI personal assistant" (Mazzucato quoted in (Wolf 2013) see also Parramore 2015). And it is not only the state which plays an unrecognized role in innovation. It is obvious, although seldom acknowledged, that the workers within an innovating firm, by being employed in an enterprise with an uncertain future, are also shouldering the risk. The same can be said of the small businesses that function as the subcontractors of the innovative firms. Once one recognizes the collective, indeed the social, nature of innovation, it is not difficult to acknowledge that not only the banks, venture capitalists and shareholders, but also government agencies, universities, research centers, employees and the subcontractors of the innovative firm, etc. are all part of the process of innovation.

As far as geoengineering ventures are concerned, a provisional conclusion here is in order: it is obvious that with RRN approach, the reward of such ventures should be distributed among a host of actors and institutions, thus reducing the share of the investors and the firm considerably. With the reduced return on their investment, it is quite doubtful that the claim of CDR's economic viability is valid.

5 Ethics and economics both

If RRN is correct, that is to say if all these agents are the real risk takers and this is the real, collective process of innovation, why has the free market economy, which is based on voluntary contracts between economic actors, not valued their role? Is RRN advancing an ethical argument or an economic argument? In this section, we argue that their economic argument has a strong ethical implication. First, we briefly review schools of ethics in order to single out a Hegelian ethics, and then, we draw the Hegelian ethical implication of RRN's economic argument.

5.1 Kantian, Utilitarian and Hegelian ethics

Different schools of thought have different notions of justice, simply because the nature of justice is one of the central problems of both political and moral philosophy (Larmore

2013, p. 276). John Rawls, perhaps the most influential contemporary moral and political philosopher, maintains that "the rights secured by justice are not subject to political bargaining or the calculus of social interests" (Rawls 2009, p. 4). Rawls's conception of justice here corresponds to that of deontological (or Kantian) ethics that maintains we are duty bound to do the right thing because it is morally right as a universal principle, and not in view of any consideration of its consequences (Singer 1995, p. 215; MacIntyre 1998, pp. 185–191). This is perhaps what in everyday usage we mean by ethics. For our purpose here, we could infer that those notions of environmental justice that recommend the right actions without any consideration for their economic consequences, particularly the imperatives of economic growth, or its corollary, profit, are in line with Kantian (or Rawlsian) ideas about ethics.

The defenders of economic considerations, however, cannot be said to be bereft of ethics. In sharp contrast to the duty-for-duty's sake of Kant, the underlying utilitarian ethics of the discipline of much of the economic science is consequentialist. Utilitarianism judges any action by its consequence for the well-being of the individuals (Van de Veer and Pierce 1994, pp. 27–30; Riley 2009). In the case of environmental justice, they have countered the deontological arguments by pointing out that any action that reduces economic growth leads to a reduction in human well-being, and hence to a more unjust state of affairs. The utilitarian approach may even acknowledge the existing environmental injustice that the deontological opponents are trying to remedy, but their counterpoint would be that a fall in economic growth leads to a worse situation than that caused by the existing environmental injustice (Shrader-Frechette 2002, pp. 15–18). From here it follows, as indeed great utilitarian thinkers have claimed, that taking a utilitarian point of view is quite in line with the Kantian ethics of categorical imperatives. Henry Sidgwick is usually regarded as the one whose elaborate utilitarianism subsumes deontological ethics (Sen 2009, p. 118), and whom John Rawls regards as the founder of ethically based welfare economics (Rawls 2007, p. 393).

There have been attempts to reconcile the environmental concerns with the utilitarian preoccupation with the welfare of the individual. From within utilitarianism, an environmental ethics can be constructed, not by questioning the welfare-centeredness of utilitarianism, but by arguing for such utility to be extended to non-human beings. Peter Singer's championing of animal rights is probably the best example (Singer 1995, pp. 180–181; 1999, pp. 284–287). But such attempts have not been wholly successful, since the utilitarian ethics can at best extend its regard for welfare as far as sentient creatures which are capable of experiencing pleasure or interest satisfaction. From the viewpoint of a utilitarian environmental ethics, the "non-sentient objects in the environment such as plant species, rivers, mountains and landscapes, all of which are the objects of moral concern for environmentalists, are of no intrinsic but at most instrumental value to the satisfaction of sentient beings" (Brennan and Lo 2016).

Maybe it is useful at this point to remember that contemporary environmentalism started with the Brundtland Report (WCED 1987), which explicitly defined the problem as the alternative win or lose situations of the economy and the environment. With the tension between the economy and the environment in mind, it seems to us that, if the idea of environmental justice and related concepts are to play a positive role in achieving the goals of sustainability, one must achieve a synthesis of the polarized positions of inconsequentialist Kantian ethics and the consequentialist utilitarian ethics. That is what, in a limited way, we will attempt in this paper, namely trying to reconcile the idea of redistributive justice (in the specific case of geoengineering ventures) with the imperatives of the economic system. Moral philosophy is a field beyond our competence, but we believe, relying for most part on the recent work of Sedgwick (2012a) and McCumber (2013), we can make a case for the plausibility of our position in the debates between ethical schools by resorting to what we take to be a Hegelian position. A Hegelian approach may best be understood as a critique of the shortcomings of the Kantian ethics. “Hegel doubts that the Kantian approach has the resources to explain why an agent would ever be moved to act morally at all” (Sedgwick 2012a, p. 2). In other words, for Hegel “moral theory is not for the purpose of ‘lecturing’” (McCumber 2013, p. 137). Recourse to any moral principle (say to *justice*) must be able to demonstrate the *necessity* of following that principle (Sedgwick 2012b, p. 8). Hegel’s method for demonstrating such ‘necessity’ is his celebrated immanent criticism, “that is taking a system of thought on its own terms, showing how it involves various internal contradictions and aporiai” (Bhaskar et al. 2010, p. 21; for more details see MacIntyre 1998, pp. 192–203).

It is perhaps necessary at this point to stress that it is not only the old Hegelian school that upholds this anti-Kantian understanding of ethics. In contemporary philosophy, from within critical realism there have been outstanding works that have subscribed to the same conclusion. Andrew Collier opens his book about values and ethics by stating that “this book can be seen as an essay in critical realist ethics. It presupposes that you can derive an ‘ought’ from an ‘is’” (Collier 1999). And of course Roy Bhaskar has extensively argued against the Kantian opposition between natural science and values, and has instead put forward an ethics which sees a continuity between nature and society (see for example Bhaskar 1998, pp 59–71).

For the purpose of this paper, the immanent critique implies that we take the logic of our present economic system as given, and then try to show that within this logic it is necessary to opt for a more *just* distribution of the rewards of geoengineering. Such a principle of redistribution is *just* because, unless this principle is followed, the economic system carries within itself contradictions which will in practice bring it face-to-face with crises. The bulk of what follows puts forward the arguments relating to such an immanent critique. We come back to the question of justice and ethics only toward the end.

5.2 The Hegelian ethical implication of RRN

To be sure, even on the face of it, RRN has strong implications for a more equitable income distribution. But for Lazonick and Mazzucato, this is directly related to the central preoccupation of the discipline of economics, namely growth. The mainstream neoclassical economics, especially in its neoliberal version, accepts the automatic distributional outcome of the free market because economic growth is driven by free market forces. Once you start interfering with the “natural” income distribution of the market (even with the best ethical intentions), you are obstructing the mechanism of wealth creation with the result that everyone would in due time be worse-off. Even for most of the welfare economists, who do not ascribe to the perfect competition and ideal free market, the engine of economic growth still lies in the market forces. For Schumpeterian economics, however, the engine of growth is in innovation. Accordingly, for RNN the more equitable distribution is a corollary of its understanding of the engine of the economic growth, which, in the Schumpeterian vein, lie in innovation. If the process of innovation is indeed a collective endeavor, then not rewarding equitably all the active partners in this process would result in less innovation, which is tantamount to forestalling growth. In other words, not complying with the ethical distribution of rewards between all risk takers has negative consequences for the economy. Unlike the Kantian approach, we briefly reviewed above here Ethics and Economy go hand in hand. That is to say, an unethical redistribution of the rewards of geoengineering would at the same time undermine the economy. Hence, neither ethical, nor economical.

And this is exactly the economic mechanism that ultimately resulted in the Great Recession that started in 2007. According to Lazonick and Mazzucato (2013), the financial institutions managed to acquire such a dominant position that they were able to extract the creative labor of all the agents of the process of innovation. This of course accounts for the widening income gaps we have been witnessing since the 1970s. But as far as economic growth is concerned, the upshot of the usurpation of all "creative labor" by financial institutions (as the main shareholders in big companies) has been the skewed calculation of risk–reward. The investment decisions in "innovative enterprises" were taken with an eye to the huge, but *uncertain*, returns, while the risk the shareholders were shouldering was only a fraction of the risk involved in the *collective* process of innovation, and the cost the shareholders were bearing was only a fraction of the cost of the *cumulative* learning in the innovation process. In short, not only did the shareholders get super-rich by depriving other partners of the rewards of innovation, but the same extraction of their creative labor blinded them to the choice of more economically rational projects. Less real innovation, hence economic recession.

6 Implications for the climate engineering

Lazonick and Mazzucato have helpfully classified the policy implications of their analysis, which ranges from appropriate government policies of taxation and direct return to the state, to mapping the division of innovative labor and distinguishing between productive and unproductive risks (Lazonick and Mazzucato 2013, pp 2020–2023). It is foolhardy to say much about the governance of climate engineering without a detailed analysis of the technology and all the firms, actors and institutions, past, present and future, involved in different branches of geoengineering from the perspective of RRN. The main conclusion of our paper is by now obvious: the "economic viability" of geoengineering is an established point only if viewed from *one* theoretical perspective in the discipline of economics, namely neoclassical economics, which, although still dominant, has been badly shaken by the Great Recession in the economy and the widening income gaps and increasing tensions in society at large. Viewed from the theoretical perspective of RRN, the economic viability of climate engineering rests on calculations that, first and foremost, are not ethical from the point of view of redistribution of the rewards. Second, such calculations of reward, exactly because of their neglect of rewarding all the real risk takers, misjudge the innovative nature of the geoengineering, which in turn promotes investment in the wrong technological sectors that could lead to a slowdown in economic growth and to recession. If the Paris Agreement targets are to be met, pursuit of a reduction in emissions seems all the more rational.

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