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Equity and Justice in Global Warming Policy

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Abstract

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Summary

Many countries are implementing or at least considering policies to counter increasingly certain negative impacts from climate change. An increasing amount of research has been devoted to the analysis of the costs of climate change and its mitigation, as well as to the design of policies, such as the international Kyoto Protocol, post-Kyoto negotiations, regional initiatives, and unilateral actions. Although most studies on climate change policies in economics have considered efficiency aspects, there is a growing literature on equity and justice. Climate change policy has important dimensions of distributive justice, both within and across generations, but in this paper we survey only studies on the intragenerational aspect, i.e., within a generation. We cover several domains including the international, regional, national, sectoral and inter-personal, and examine aspects such as the distribution of burdens from climate change, climate change policy negotiations in general, implementation of climate agreements using tradable emission permits, and the uncertainty of alternatives to emission reductions.

Keywords: Economics of Climate Change, Intragenerational Equity, Distributive Justice

JEL Classification: D62, D63, H23, H41, Q00

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1. Introduction

Equity is a major criterion on which to base any policy (Rawls, 1971), also environmental policy. In this paper we focus on climate change policy as climate change is characterized by several unique considerations that make equity especially important. First it is a transboundary problem of global scale. This means it requires a global solution. Since there is no supra-national authority to impose policy remedies, the solution requires the voluntary cooperation of sovereign states. International treaties, such as the Kyoto Protocol, have made progress in gaining cooperation, at least among industrialized countries.[2] One feature of the treaty that helped garner cooperation was a set of "flexibility mechanisms" that capitalize on the mutual gains from trade, such as multilateral emissions trading, or more modest bilateral cooperation through Joint Implementation and the Clean Development Mechanism. These policy instruments have the potential to reduce the overall costs of mitigating greenhouse gases (GHGs) substantially. However, appeals to cost-effectiveness have not been enough to bring many countries on board, and there are strong indications that equity and related issues are the dominant considerations. In essence, many are concerned about the cost impact of the mitigation burden on themselves and in relation to others. Several principles of fairness have been used as excuses for not ratifying the treaty. For example, the U.S. has pointed to the fact that several large emitters, such China and India, have not committed to GHG reduction. In turn, developing countries point to their relative lack of resources and the fact that the industrialized countries failed to do anything about the problem when they were at a similar key stage of economic development. Less attention has been paid to the uneven international distribution of the negative impacts (and even some positive impacts) of climate change on human health, other species, resources and the environment, but this is an important issue as well.

Another relatively unique equity consideration relates to the time horizon of the climate change problem. GHGs have long residence times in the atmosphere, in some cases as much as thousands of years. Hence, the actions of the current generation have profound implications for those in the future. The intergenerational equity issue and the associated sustainability

[2] The Kyoto Protocol calls for the reduction of the six major categories of greenhouse gases (GHGs) for the first compliance of 2008-12. The original signatories in 1997 were thirty-eight industrialized and transitional economies, including the U.S., agreeing to an overall 5.2 percent reduction in GHGs. To go into effect, the treaty required that at least 55 percent of the world's countries, generating at least 55 percent of total GHGs, ratified the treaty. This threshold was attained in February 2005. The U.S. signed but never ratified the treaty. Several other large countries including China, which recently surpassed the U.S. as the largest emitter of carbon dioxide, have not ratified the treaty as well.

issues are, however beyond the scope of this paper, which will focus on various aspects of intra-generational burden sharing. The reader is referred to Arrow et al. (1996) and also the discussion of the Stern Review (Stern, 2007), such as the papers by Dasgupta (2006), Nordhaus (2007), and Weitzman (2007).

While the international domain is the main focus in this paper, we will also examine other aspects of equity. Equity is important at two levels of policy below the international level. Although the U.S. has not ratified the Kyoto Protocol, hundreds of its cities, states, and regions have made commitments to the Protocol or to remission reductions in general. Several cooperative ventures are underway, including the Regional Greenhouse Gas Initiative (RGGI) among several Northeast and Mid-Atlantic States. Although interregional equity issues were downplayed in the original formation of this cooperative arrangement, they are starting to rise in terms of participants wanting to renegotiate their original commitments as the target date nears and the difficulty of implementation becomes more imminent. More recent efforts, such as the Western (States) Climate Initiative (WCI), are starting to address equity issues more actively at the outset of their negotiations. Although disparities are not as great in the context of a single country as in the international case, tensions can become sizeable, especially since competitive changes and relocation possibilities are more evident. Moreover, conflicts of fiscal federalism, such as which jurisdiction should control carbon tax or emission permit auction revenues, loom on the horizon as momentum in the U.S. grows for a national strategy based on nation-wide emissions trading. However, states may be reluctant to cooperate in a national effort. If emissions permits are auctioned rather than freely granted, or if a carbon tax is implemented instead to supplement emissions trading in some sectors, the control over sizeable revenues is at stake. In addition to arguments over rights and power, equity concerns are already being voiced in relation to state needs and the traditional unevenness of the distribution of federal expenditures out of any revenues.

Another level of analysis can be performed at the meso-scale in terms of the distribution of policy impacts across sectors. Again, climate mitigation policy is rather unique, in that its impacts are likely to fall heavily on a narrow range of sectors. Because most GHG emissions emanate from fossil fuel extraction, transformation, and end-use, the coal, oil, and gas sectors are likely to be most affected. Ordinarily, uneven sectoral impacts may not receive much attention or sympathy. However, the impacts on these sectors might be extreme to the point of a demise of the coal industry in many countries. While mine owners may be among the high

income group members, mine workers, especially those who are not unionized, are closer to the bottom rungs, and inhabit many relatively poor regions such as Appalachia in the U.S. At the same time, some sectors are likely to reap sizeable rewards, including renewable energy and perhaps nuclear power. The agricultural and forestry sectors may gain sizeable revenues as well from plant sequestration for carbon, and the oil and gas industries through geological sequestration.

Another level of concern over equity is at the inter-personal level, where the traditional focus is on the size distribution of income. Policy instruments are often evaluated in terms of their progressivity (i.e., whether higher income groups are impacted more than lower income groups). Climate change policy is somewhat unique here as well, because it bears heavily on energy prices, prices of a basic necessity. It is not surprising that most studies to date indicate that carbon taxes or emissions trading are likely to be regressive. Beyond income groups, there are other interpersonal dimensions. Another unique aspect of climate change itself is that it would have relatively stronger adverse effects on the aged or infirm, primarily through higher temperatures but also through health-related effects relating to water quality and the increase in vector-borne infectious diseases.

Still another equity dimension relates to race and ethnicity, which is the basis for the modern Environmental Justice (EJ) movement, a combination of activism and intellectual inquiry. The movement's original focus was on the fact that many toxic waste sites were located in or near minority neighborhoods. Although one explanation is that the poor tend to reside closer to industrial sites because of lower property values, the EJ conclusion is that minority groups are hit even harder because of their lack of political power and a tradition of exploitation. This has led to opposition to emissions trading. Although the location of GHG reduction does not matter because it is a globally-mixed pollutant, reduction of co-pollutants (e.g., sulfur oxides, particulates, air toxics) does. In this light, minority neighborhoods might not gain a potential reduction of these co-pollutants if the major local emitters buy permits and thereby refrain from taking actions that will lower emissions of all pollutants. In a related vein, many GHG mitigation measures have the ability to generate jobs related to mitigation in these local areas if permits were not purchased there.

The distribution of impacts is important for more than just normative reasons. The energy industry is a powerful interest group in many countries or regions, and these uneven impacts have already given rise to a call to arms and effective blocking of many climate change policies. The uneven sectoral impacts can be muted significantly by flexibility in trading across geographic areas and sectors, as well as trading over time (permit borrowing) to allow for technological change, such as bringing down the cost of carbon separation and capture, and reducing the possibility of seepage from geological sequestration). Likewise, there is increasing sensitivity to the plight of the poor and minorities in many countries, and the climate policy that is likely to result in inequities in these arenas will have a much more limited chance for approval and implementation.

Extensive academic research and practical ingenuity have been brought to bear on the various dimensions of equity and climate change policy. In this paper, we summarize and critically evaluate the literature and the evolution of recent policy in this area. The emphasis is on the international domain, where most of the research and practice has taken place. In section 2 we begin by defining central concepts such as efficiency, equity and justice, as well as summarizing the main theories underlying these important concepts. This is useful to understand the discussion in the following sections, where we first start with the burdens of climate change and climate change policies, focusing on both the burdens following from climate impacts as well as mitigation (Section 3). Section 4 surveys questions of equity in international climate negotiations, while section 5 focuses on the implementation of climate agreements using price incentives (taxes and tradable emission permits). We then take a look at equity principles that have actually been used (Section 7), and in Section 8 we shortly discuss equity and uncertainty giving examples from geoengineering and adaptation. We conclude with some suggestions for further research.

2. Theories of equity and justice[3]

2.1 Definition of concepts

The concepts of efficiency and equity are central in policy analyses. While Pareto Optimality, a situation characterized, in part, by no waste of resources, is an accepted efficiency principle, there is not a consensus on a “best” equity principle. As a result, most economic analyses have concentrated on efficiency problems, and equity often plays a secondary role in

[3] The discussion in this section is based heavily on our previous work (see Rose and Kverndokk, 1999, 2004; and Kverndokk and Rose, 2004).

economic policy making (Johansson-Stenman, 1998), even if it will always play an important role as a principle of social interactions.

While equality usually means equal allocations of resources or egalitarianism, distinguishing between the related concepts of equity, fairness, and justice, may in general be difficult, and many of the studies on global warming policies referred in this paper do not attempt to make extensive distinctions. However, both fairness and equity are often given a specific meaning in economic theory and philosophical theories of justice and alternative equity principles exist (see 3.3. below).[4] Justice is sometimes taken to be an umbrella term, incorporating all dimensions of evaluation besides efficiency (see, e.g., Hausman and McPherson, 1993). For instance equality is central in John Rawls definition of justice (Rawls, 1971).

Another distinction is between is between fair, equal or just on the one hand, and good on the other. While in many analyses these concepts do not mean the same thing as good, they may also help provide a precise definition to what is good. For instance, in ethical reasoning, there are two ways to justify if an action is good or bad. The first is to refer to the consequences. Based on this, an action is good if it is the best way (e.g., least effort) to attain the aim we strive for (e.g, maximize welfare, reduce greenhouse gas emissions). This is often referred to as substantive fairness or consequentialism, and is also related to distributive justice, which is concerned with the allocation of scarce resources (Roemer, 1996). Thus, in our context this would mean incidence of benefits and costs.

However, another way of moral thinking states that consequences alone do not guide us whether something is right or wrong (procedural fairness). This is related to the process by which outcomes are reached. It is not enough to know that the action is the most effective way to attain the aim. Thus, the claim that the "ends justify the means" is not necessarily true according to this way of moral thinking.

2.2 Welfare maximization

[4] Some examples are Feldman and Kirman (1974) who define fairness as non-envy, i.e., no agent prefers what another has to what he himself has, while Varian (1974) defines equity as non-envy and a fair allocation as both equitable and Pareto efficient. Another often used criterion of equity is proportionality (see e.g., Konow, 2000), where the fair rewards are in proportion to the contributions that individuals' control, such as hours worked, but are not related to factors they do not control such innate abilities or inherited wealth.

One branch of mainstream economics addresses equity by formalizing the concept of a Social Welfare Function (SWF), which is able to rank all states of the economy, and thus policy outcomes as well, on the basis of performance criteria such as efficiency and equity. One advantage of the approach is that it is able to separate these two criteria, though tradeoffs between them can still prevail. Although many alternative equity principles exist (see 3.3 below), the one most prevalently used in this approach is "vertical" equity, which holds that equity increases as utility (or income) disparities between individuals decrease.

The Fundamental Theorem of Welfare Economics stipulates that a perfectly competitive economy will achieve an overall efficient (Pareto Optimal) allocation of resources. However, the market is blind to equity, so efficient outcomes as well as inefficient outcomes in the presence of externalities like pollution, may have undesirable distributional implications, giving rise to calls for remedial policy. The approach makes efficiency-equity tradeoffs clear. For example, progressive taxation is typically believed to have equity-promoting, as well as inefficiency causing effects. The size of such disincentive effects is of course an empirical question, although many studies indicate that they are in practice rather small (e.g., Danziger et al., 1986). We can be more certain of achieving equity with the minimum of efficiency loss if we utilize "lump sum" transfers, or if we avoid price-distorting policies. The difficulty is that in practice there are few lump sum transfers, i.e., transfers that are not based on effort.

One way out of the efficiency-equity tradeoff is offered by the Coase Theorem (Coase, 1960), which states that in the case of externalities the delineation and assignment of property rights will lead, through market exchange, to an efficient allocation of resources, irrespective of how the rights are distributed (assuming transaction costs are small and that there are no significant income effects). For years, the secondary clause of this theorem--that the distribution of property rights would not affect efficiency--was used as a justification to ignore equity, since it had no affect on efficiency. Ironically, it now offers a reason to address it. For example, as noted in the introduction, equity is especially important where voluntary cooperation is required so distributional issues do matter. Moreover, one of the major ways to influence the equity outcome of mitigation policy is to use an emissions trading approach and to adjust the initial allocation of permits accordingly. This is further discussed in sections 3.3 and 5.3 below. Thus, equity can be addressed head-on without undercutting efficiency. Alternatively, equity can be promoted in a case of a carbon tax by the redistribution or spending of the

carbon tax revenues, see section 3.4. However, in this case, redistribution may not have the attractive neutral feature of the Coase Theorem with regard to the equity-efficiency tradeoff.

2.3 Social justice

A theory of justice is a normative theory. Such a theory has two aspects. First, it will regulate individual rights (and duties), and second, it will propose or evaluate a distribution of goods (and burdens). Different theories of justice may weight these two aspects differently. They are, for instance given equal weight by utilitarians[5], while Rawls (1971) gives political freedom and rights a lexicographical priority over economic distribution.

Below, we consider philosophical theories of justice (global justice theories), i.e., theories that are centrally designed for the whole society and are intended to compensate people for various sorts of bad luck, that may result in low levels of income. We will not consider theories for decentralized distribution decisions (local justice theories), that are considered independent of other distribution decisions, such as who shall perform military service, who shall receive organs for transplantation, etc., but will focus on theories that provides suggestions to society-wide problems such as income distributions (Elster, 1992). The framework is general and relates to many issues including environmental problems.

2.3.1 Utilitarianism

Utilitarianism is a sub-set of welfarism, i.e., theories that focus on welfare outcomes. The utilitarian aim is to distribute goods so as to maximize the total utility of members of the society, where “goods” are interpreted broadly to include economic goods, rights, freedom, and political power (see, e.g., Harsanyi 1955). A utilitarian welfare function is usually defined as the sum of the utility of all the members, i.e., all individuals have an equal weight. One problem with this function as well as for other forms of SWFs, is the interpersonal comparison of utility, which is not a straightforward issue. We will not examine these problems in this paper, but refer to, e.g., Arrow (1970). Even though utilitarianism does not explicitly address equity, its welfare maximization objective does have distributional implications as it proposes a certain distribution of goods as the optimal outcome.

2.3.2 Rawlsian theory

[5] Given that the arguments in the utility function can be both goods and rights.

The theory of Rawls (1971) is basically a critique of utilitarianism. According to Rawls, utilitarianism has no respect for individuals. A person is not seen as valuable and worth protecting on his/her own right. Rawls argues that a theory of justice should respect the individuals as ends in themselves.

The methodological starting point of Rawls theory is the "original position." Many would argue for what is just or unjust depending on their own position in the society. Therefore, as a starting point to decide the basic structure of the society, which according to Rawls is the primary subject of justice, we have to think about a hypothetical and idealized world where all individuals sit behind a veil of ignorance; the original position. They do not know their abilities, sex, race or position in the society. All they know is that they are going to live in the society. In this hypothetical situation, Rawls argues that they will agree on certain principles:

First principle:
Each person is to have an equal right to the most extensive total system of equal basic liberties compatible with a similar system of liberty for all (Rawls, 1971; p. 250).
Second principle:
Social and economic inequalities are to be arranged so that they are both:
a) to the greatest benefit of the least advantaged, and
b) attached to office and positions open to all under conditions of fair equality of opportunities (Rawls, 1971; pp. 302-3).

The first principle, the "Principle of Greatest Equal Liberty," is about individual rights (e.g., freedom of thought and liberty of conscience). As it has a lexicographic priority, none of the basic liberties should be traded against material advancement. However, it is the first part of the second principle, the "Difference Principle," that is mostly referred. One usual misinterpretation in economics is that Rawls argues for maximizing the utility of the least advantaged. But his theory is not utilitarian, and he argues for distributing "primary goods" (goods everybody needs to realize his/her plans of life independent of what the plan is). While the first principle distributes one subset of primary goods, the basic liberties, the Difference Principle distributes another subset including wealth, income, power, and authority. The last part of the second principle, the "Principle of Fair Equality of Opportunity," requires that we go beyond formal equality of opportunity to insure that persons with similar skills, abilities, and motivation enjoy equal opportunities.

Several critics have argued that Rawls went too far in reacting against welfarism. For example, Sen (1980) argues that primary goods are not the appropriate maximand. The focus should be on what goods do for people such as enabling people to escape from morbidity, to be adequately nourished, to have mobility, to achieve self-respect, to take part in community life and to be happy. Sen calls these functioning, and argues for equalizing them. For instance, if all primary goods except income were equalized among people, Rawls would argue that income should be equalized as well. However, a handicapped person would require more income than an able-bodied one, and needs a higher income to function in the same way.

The most interesting new aspects of distribution and environmental policy pertain to transboundary pollution and the fairness of policies across regions and nations. However, Rawls' original theory is basically a theory of justice within a nation. In his later work (Rawls, 1999), he is concerned about international justice. He argues that the welfare of the citizens is mainly the responsibility of the nation states and that the international community has a more supportive function, which is to secure a setting where national societies can develop positively. In addition to principles in his original theory he adds duties to honor human rights and to assist peoples in unfavorable conditions. This would also include international transfers to disadvantaged countries.

2.3.3 Libertarian theory

In libertarian theory, the baseline is that individual freedom prevails except where others may be harmed. Thus, this is in the same line as Pareto superiority saying that there is an improvement in welfare if one or more persons are made better off due to change in resource use as long as the other persons are at least as well off as before.

Nozick (1974) has provided the best-known statement of libertarian thought. The theory can be summarized in three principles: justice in appropriation, justice in transfer, and justice in rectification. A distribution of goods is just if it is the end result of an unbroken chain of just transfers, beginning from a just original appropriation. If these conditions are not satisfied, justice in rectification requires that we should establish the distribution that would have occurred if all unjust links in the chain had been replaced by just ones.

The first principle is a “finder’s keepers” principle, where the idea is that anyone has the right to appropriate, exploit, and enjoy the fruits of any unowned piece of nature. The principle of just transfers says that the outcome of any voluntary transaction between two or more individuals is just if there is no coercion. If individuals agree on a contract that will benefit all, there is no reason to stop the contract apart from the case where anyone uses its power to make the non-agreement state worse for the other parties. The last principle is the main weakness of the theory, as identifying the point in time where the earliest violation occurred and, thereafter, the counterfactual chain of just transfers, may be rather indeterminate.

2.4 Principles of equity and justice

We would like to distinguish between equity and justice principles. “Equity principles” may be defined as normative criteria for how a society should be organized, how goods or burdens should be distributed, etc. (see, e.g., Rose, 1990). On the other hand, “principles of justice” are basic rules underlying theories of justice, as most theories of justice are quite coarse-grained. Thus, they can be interpreted as side constraints to these theories. Several principles of justice may be in accordance with one equity principle, and vice versa, see section 5.3 below.

Several global theories of justice give different equity principles for the distribution of goods and rights, see section 3.3 below. However, there may be common denominators in theories of distributive justice. Meta-principles are principles implicit in all global theories of justice. Elster (1992, 1993) claims two such meta-principles to be “ethical individualism” and “ethical presentism.”

The view of ethical individualism (EI) is that justice is attached to individual human beings. It is a denial of supra-individual and non-human justice, the first treating groups, and the latter organic or inorganic nature, as subjects of justice. There are two claims of EI: (i) theories of justice should allocate goods among individuals, and (ii) this allocation should be made on the basis of information about individuals (Elster, 1993).

The basis of ethical presentism (EP) is “... that past practices are irrelevant to distribution in the present, except to the extent that they have left morally relevant and causally efficacious traces in the present” (Elster, 1992; p. 200). A few examples may clarify this meta-principle. First, no one should have to suffer from crimes committed by his or her parents; one cannot

choose ones parents. Nevertheless, if people are worse off today than they otherwise would have been because of discrimination against their parents, a claim for compensation is compatible with EP. However, compensation does not follow from EP, since meta-principles are only constraints in a justice evaluation. On the other hand, if people are worse off today because their parents wasted their resources, compensation is not compatible with EP.

2.5 Environmental justice

This approach to environmental policy differs from mainstream approaches at the outset, because it gives primacy to concerns about equity. It also differs in that focuses on the object of equity as disparities according to race, as opposed to income or other socioeconomic characteristics. Further, it integrates community activism with conventional and unconventional analysis and communication. Finally, its focus is typically local, though this has important bearing on the design and implementation of broader climate policy (see, e.g., Pastor, 2007). Recent extensions to to global issues (se, e.g., Kutting, 2002; Hamilton, 2005) have not extended to climate policy at that scale, however.

The EJ approach is especially skeptical of efficiency goals and explanations. Various independent scholars, faith-based groups, and government agencies have found a disproportionate number of hazardous waste sites in and around minority neighborhoods in the U.S. and several other countries. One explanation is that land values are lower there before the siting or after, and therefore that these locations are more prone to be inhabited by lower income groups. However, even controlling for income, many studies have found race to be a factor (Hamilton, 1995; Morello-Frosch et al., 1997). The explanations then range from mainstream concept of asymmetric information to more radical theories of exploitation. Moreover, despite government efforts to remedy the situation in the U.S. since the early 1990s, the federal government's own report indicates that little progress has been made (Report of the Office of the Inspector General, 2004).

In the U.S., this perspective presents a possible obstacle to the implementation of cap and trade. Although GHGs are globally mixed pollutants, various co-pollutants of combustion and other processes are not. Thus, there is a concern that, locally, mitigation and permit purchases are not equivalent from an environmental standpoint. A locality or region that purchases permits to avoid having to mitigate GHGs would forego the opportunity for a reduction in particulates, sulfur oxides, air toxics, etc., and might even witness an increase up to the

criteria pollutant limit. From an economic standpoint, the decision differs as well. The purchase of permits may be in the best interest of the emitting firm, but may not be so from the standpoint of the community. Some types of mitigation are seen as an opportunity to create additional jobs. At the same time, the job loss due to inefficient choices by emitting firms (passing up lower cost permits in favor of local mitigation) is not usually considered. Counter-arguments that permit auction revenues can be used to offset negative environmental or economic consequences are not well received by the EJ community given the severity of potential health problems from some co-pollutants and the distrust of government promises.

Ironically, in one major way the EJ situation is just the opposite if extrapolated to the international level. Developing countries, typically comprised of non-whites, have relatively more low-cost mitigation/sequestration options and are thus more likely to be permit sellers and hence mitigate proportionally more of all pollutants than would industrialized countries.

Another example where minority groups, as well as the poor in general, may be hit relatively harder by environmental policies is biofuels (see, e.g., Runge and Semaver, 2007). Corn prices have increased as corn is used in ethanol production, which has lead to higher food prices in the U.S. and in developing countries, culminating, for example, in tortilla riots in Mexico. Also, the demand for biofuels has had a negative impact on the Amazon and people living there. As soybean farmers are switching to corn in the U.S., Brazilian soybean farmers are displacing cattle pastures and these in turn are displacing the Amazon forest.

In the remaining sections, we will discuss equity in climate change policies. While the equity problems discussed are mainly about distributive justice (consequences), we will also discuss procedural justice. As mentioned in the introduction, we will focus on intragenerational justice problems. Intergenarational justice related to global warming are mainly concentrated around the question what we should aim for, or how large the emissions or atmospheric concentration target should be. On the other side, intragenerational justice is mainly concerned about how we should distribute the burdens. While the distinction sometimes can be difficult, the discussion below gives some examples of intragenerational equity and justice related to global warming that have been discussed in the economic literature.

3 The burdens of climate change and climate change policies

3.1 Who suffers most from climate change?

Over the next decades, the world will probably face large climatic changes in form of increased temperature, sea level rise, changed wind and precipitation patterns, more extreme weather, etc. (IPCC, 2007). However, the damage of climate change will not be evenly distributed among countries or among the individuals in a country (Tol et al., 2000; Tol, 2002a,b; Yohe et al., 2007). For increases in global mean temperatures less than 1-3˚C above 1990 level, some impacts will be beneficial to some sectors and regions while costly to others, e.g., agricultural production may increase in Northern Europe, while it may be reduced in large parts of Africa. Global mean losses are expected to be 1-5% of gross domestic product (GDP) for 4˚C of warming, with larger losses in developing countries, and the net damage costs of climate change are likely to increase over time. Vulnerabilities also differ considerably between regions, and poorer countries will face higher negative impacts than richer countries. Development may, however, reduce overall vulnerability to climate change as richer countries seem to have a higher ability to adapt. The unequal distribution of impacts makes this a concern of distributive justice.

While the estimation of damages is tied up to intergenerational equity as this represents a present value estimate, meaning that the discount rate is important (see, e.g., the discussion around Stern Review), there is also one aspect of intragenerational equity involved in the aggregation of damage estimates due to the uneven distribution of income across individuals and regions. One problem with damage cost estimates is that the values depend on income. Using the standard methodology from economics such as willingness to pay or accept, rich people (or countries) are willing to pay more or to require higher compensation than poor people (or countries). This means that even if consequences of global warming may be more severe in poor countries measured as lives lost, loss of biodiversity or in production measures such as GDP, the aggregated measure of damages may be lower than in richer countries. To deal with the unequal income distribution, one methodology that has been proposed in the literature is to use equity weights. The idea is that a dollar to a poor person is not the same as a dollar to a rich person, meaning that we cannot add up monetized losses. Instead we should add up welfare losses and then monetize. It follows from this that we should attach different weights to a given monetary loss, where the weight is higher in a poor country than in a rich country as the weight depends inversely on the income level.

Equity weights have been discussed in cost-benefit analyses for several decades (see, e.g., Little and Mirrlees, 1974) and an early contribution in the context of global warming is Fankhauser et al. (1997). They showed that the aggregate damage figures based on equity weights significantly depend on the social welfare function chosen.[6] A recent study is Anthoff et al. (2007), who chose a utilitarian welfare function, and concluded that equity weighted estimates of the marginal damage of CO_2 emissions are substantially higher than estimates without equity weights (by a factor of ten or more depending on the pure rate of time preference etc.). To find the monetary estimate of damages, the authors argue that the estimates should be normalized with the marginal utility of consumption of a specific region, and the estimates may also vary considerably with the region chosen. Further, estimates are also sensitive to the intraregional income distribution as well as assumptions on inequality aversion. The latter is important as different scenarios have different income distributions. The conclusion that the use of equity weights increases damage cost estimates is interesting. While the Stern Review (Stern, 2007) has been criticized for its high damage cost estimates due to a low discount rate (Nordhaus, 2007; Dasgupta, 2007), the review does not use equity weighting explicitly.[7] Thus, taking the uneven income distribution seriously may actually increase the damage cost estimates in the Stern Review.

The fact that estimates vary depending on the social welfare function is a problem for policy making. When a specific welfare function is chosen, ethical views as well as other specific assumptions are made at the same time. Equity weighting assumes a social planner and specific social welfare function, but it is hard to formulate a social welfare function that represents the ethical views of all agents (Brekke et al., 1996). Another problem with equity weighting is that it has to be used consistently in economic policymaking and not just in some areas such as climate policy in order for policy making to be consistent. Further, aggregation of welfare losses across different countries assumes a supranational perspective such as a global social planner, but decisions are made by national decision makers. This is studied in Anthoff and Tol (2007), who focus on international equity weights in climate policies under national decision-making. They study four different ethical positions taken by the decision makers. In the first, decision makers do not care about what happens abroad (*sovereignty*).

[6] Johansson-Stenman (2000) shows, however, that some of the most extreme and unintuitive results in Fankhauser et al. (1997) depend on misunderstandings with respect to permissible transformations of the utility function.

[7] The Stern Review recognizes equity weighting and increases the damage costs by 25% based on calculations in Nordhaus and Boyer (2000). However, the impacts of equity weighting are much lower in the Nordhaus and Boyer study than in most other studies, see, e.g., Anthoff et al. (2007) referred above.

Second, they are altruistic towards people living in other countries (*altruistic*). Third, the decision makers compensate damages done abroad (*compensation*), and fourth, the national decision makers feel responsible for damages done abroad, but cannot compensate (*good neighbor*). The different ethical views give very different estimates for marginal damage or carbon taxes (given that the tax is set equal to the marginal damage) at the national level, with the highest tax for good neighbors and lowest in the sovereignty case. Thus, this shows that a wide range of carbon taxes can be defended based on different ethical positions.

The use of equity weights also triggers the discussion of equity versus efficiency. If one does not care about equity at all at the social level, introducing equity weights will imply large inefficiency losses (Harberger, 1978).[8] If one cares about equity, one alternative to base the policy on equity weighing is to redistribute income as when the income distribution is just, distributional weights will be identical (Fankhauser et al., 1997). It has been argued that it is socially inefficient to use equity weights in cost-benefit analysis and that this implies large inefficiency losses when distributional matters can be dealt with through income taxation instead (Hylland and Zeckhauser, 1979). While this may be a difficult task in international climate policy, Johansson-Stenman (2005) challenges this argument within a general framework in the context of national decision making, and shows a large range of cases where equity weights are (second-best) optimal to use. However, he concludes that the question of whether equity weights should be used cannot be answered in general, but depends on the proposed project or policy instrument.

3.2 Will mitigation costs be evenly distributed?

To avoid large impacts of climate change, greenhouse gas emissions reductions are necessary.[9] This would require increasing energy efficiency of production or even reduced production, interfuel substitution, changes in land use configurations, or other practices, most of which could lead to lower consumption levels. However, the costs of greenhouse gas mitigations are not evenly distributed among regions or countries. The recent IPCC report confirms the earlier reports in that even if the overall mitigation costs may not be very high[10],

[8] One amusing example given in Harberger (1978) is to send ice-cream on camel-back across the desert from a richer oasis to a poorer one. With a high social inequality aversion, Harberger finds that "up to 63/64 of the ice-cream could melt away without causing the project to fail the test".
[9] Geoingeneering and other alternatives are discussed in Section 7.
[10] The costs of committing to the Kyoto Protocol may be less than 0.1% of GDP in Europe with flexible permit trading. Also, stabilization targets such as 550 or 650 ppm CO2-equivalents may be reached to a cost of about 1% or lower of global GDP by 2030.

the best economic potential for emission reductions is probably in non-OECD countries (Barker et al., 2007). Thus, cheap reduction options are mainly found in Eastern Europe and developing countries. [11] In general, the mitigation costs of a country mainly depend on the level of energy-efficiency, the production structure, and the availability of renewable energy sources. We should also note that mitigation policies in one region have impacts on other regions in terms of their emission levels and mitigation costs, due to impacts on fossil fuel prices, competitiveness, technology spillovers etc.

Above, equity weights were discussed as a way to aggregate and compare different damage cost estimates of climate change. The question remains if equity weights are relevant when it comes to mitigation costs. Azar (1999) shows that equity weighting may be appropriate here as well. Optimizing a global social welfare function, assuming that the world consists of a rich and a poor region, would require equality weights used also for mitigation costs in the poor region, but not in the rich. This follows as costs and benefits are normalized with the marginal utility of consumption in the rich region (see also Anthoff et al., 2007). In his approach, even if different weight factors used in the literature give substantially different damage estimates, they yield the same optimal emission reductions. The reason is that also mitigation costs are weighted in the same way, and this offsets the effect of different weighted damage estimates. This will be further discussed in Section 4.[12]

3.3 Equity principles of burden sharing

Because there is no consensus on a best definition of equity, several alternative criteria have been put forth for the interregional and international analysis of the equity implications of environmental policy, most of them being extensions of interpersonal equity principles discussed above (Rose, 1992). Ten equity principles, a general operational rule emanating from each, and a corresponding rule applicable for the example of the allocation of tradable emission permits at the national level are presented in Table 1.[13] The principles are divided

[11] For instance smaller CO2 emissions reductions (5-15%) by 2010 in China may give potentially positive GDP effects due to a double dividend effect (Garbaccio et al., 1999).

[12] Another intragenerational equity aspect is also important for optimal emission reductions. As mentioned above, Anthoff et al. (2007) found that damage estimates are sensitive to the inequality aversion. This is further confirmed in Shiell (2003) who calculates optimal global greenhouse gas emissions under various inter- and intragenerational equity assumptions including discounting and different equity weights for different world regions. She finds that the traditional conflict between ethical approaches (prescriptive) and market approaches (descriptive) can be significantly moderated with the introduction of another dimension of equity, namely the inequality aversion parameter in the utility functions.

[13] The principles presented are discrete measures of equity. A more general, continuous formulation of equity based on the Atkinson Inequality Index is examined by Eyckmans et al. (1993).

into three categories. The first is “allocation-based’ criteria, which focus on the before-implementation (before-trading) implications for mitigation costs. The “outcome-based” criteria focus on the post-implementation position, which would include mitigation costs and permit revenues/expenditures, as well as the benefits of the mitigation. The “process-based” criteria focus more on the conditions that lead to the outcome distinguishing between ideal political conditions, pragmatic political conditions, or pure market forces, respectively.[14]

[Insert Table 1]

Of course, there are other levels of application of equity criteria, including sectors and households. In some ways, these units are superior to regions, because they address the issue of relative impacts in terms of welfare of the individual (the basic unit in a democracy). Although policy-making will take place at a more aggregate level, it is important that equity at the international and interregional levels filter down to the micro (individual) level, for which economic welfare is measured.

To be operational, an equity criterion must be applied to a “reference base”, essentially a metric or index, which by itself has no ethical content, i.e., it is a quantity to which a specific value judgement needs to be applied to give it any explicit normative implications (Rose, 1992; Rose and Stevens, 1998). Examples of reference bases are income, energy production, energy use, population, GHG emissions, etc. To illustrate the use of equity principles, consider permit trading and the following six permit allocation formulas for the initial allocation of permits[15] (consisting of an equity criterion and an associated reference base) applied at the regional level, where the reference base is in the parenthesis:

1. Sovereignty (emissions based)
2. Sovereignty (energy-use based)
3. Sovereignty (energy-production based)
4. Egalitarian (population based)
5. Economic Activity (GRP based)

[14] Most of the principles presented in Table 1 are altruistic in nature. For an approach to equity issues based on self-interest discussed in other portions of this review, the reader is referred to UNCTAD (1992) and Barrett (2005). Altruistic principles are more consistent with most notions of justice and fairness than are the non-altruistic principles such as the Kantian imperative and "absence of envy."

[15] In section 5.3 below, we take a further look at the initial permit allocation from a philosophical point of view.

6. Ability to Pay (inverse-GRP based)

Note that there is not a one-to-one correspondence between criteria and reference bases. For example, the Sovereignty criterion can be implemented according to more than one reference base, and Gross Regional Product (GRP) can serve as a reference base for more than one criterion. Reference base distinctions are important for several reasons. First, as in the case of three bases applied to the Sovereignty criterion, they can reflect alternative energy policy positions. For example, Formula 5 simulates a "downstream" administered program on fossil energy end-users, while Formula 6 simulates an "upstream" program on fossil energy producers. Most importantly, the welfare implications of various references bases for the same equity criterion will differ as well, because each reference base leads to a different set of permit allocations and hence a different set of sales/purchases outcomes.

The results of the application of the six equity formulas for permit trading to the sharing of the Kyoto Protocol target within the U.S. by Rose and Zhang (2004) yield some interesting results. First, for some of the formulas (e.g., Sovereignty/Energy Use), there is very little variation of welfare gains across regions, primarily because the mitigation costs before trading are relatively uneven and the volume of trading is not large. Second, for some regions (e.g., Southwest, Mid-Atlantic, New England) there is little difference across equity formulas, primarily because their permit allocations vary so little. For some regions, the equity formula does matter greatly (e.g., South Central, North Central), because of the positive correlation between their per capita incomes and population. The results on this score differ greatly from their application in the international domain. For example, the egalitarian (per capita) criterion leads to the relatively lowest cost burden being incurred by one of the regions of the U.S. with the highest per capita income (North Central States), because this is also the most populous region. This is just the opposite of the result in the international domain, where countries such as China and India stand to gain the most from application of this criterion.

Interestingly, the Rose-Zhang study and many on permit trading at the international level (see, e.g., Rose and Stevens, 1998; Rose et al., 1998) indicate that although equity principles differ significantly from a philosophical standpoint, many of them yield very similar outcomes in practice in terms of net costs alone, or even net benefits when avoided climate damage is considered (see also the similar conclusion by Ringius et al., 2002, with regard to the practical application of a set of equity principles that overlap somewhat with those presented in Table

1). The main outlier is the egalitarian principle, especially in the international context given the huge populations of China and India, which would result in transfers in the hundreds of billions of dollars per year and is thus politically untenable. The reason for the relative homogeneity of outcomes is explained by features of the three major aspects of the determination of net benefits of climate policy. First, benefits (avoided climate change damages) are the same no matter how the permits are allocated. Second, according to the Coase Theorem, there is a unique equilibrium (in this case mitigation costs) after property rights (emission permits) are exchanged, so this aspect does not vary. Third, the only feature that does vary is the purchase and sale of permits. Thus policy-makers might wish to look beyond philosophical issues in the negotiation process if they don't result in practical differences. Arguing over fine points for some equity principles may not be time well spent if the equity outcomes are relatively even for them not only in the case of permit trading but in general.

3.4 The incidence of climate change policy

In addition to emission permits, a carbon tax is also a policy instrument for mitigating climate change impacts that is often applied in economic analysis. A number of studies have examined the income distribution impacts of carbon taxes or carbon emission permits (see, e.g., Harrison, 1994; Dinan and Rogers, 2002; the reviews by Repetto and Austin, 1997; and Speck, 1999; and the more general review of incidence of pollution control in general by Parry et al., 2007). We begin by summarizing the three special features most emphasized to distinguish the impacts of these policies in contrast to the incidence of taxes in general.

First, although the initial focus is on a few but very prominent sectors that emit carbon (Coal/Oil/Gas extraction, transportation, and refining), the fundamental role of these products, however, means that carbon reduction policies will eventually ripple throughout the economy, with possibly surprising outcomes. This is one of the major reasons general equilibrium models are often used to evaluate incidence.

Second, fossil energy products and most energy-intensive processed goods (food, housing, and automobiles) are necessities, making it relatively more difficult to substitute away from them. Spending on necessities is inversely related to income, and, hence, all other things being equal, carbon taxes would lean toward being regressive in partial equilibrium terms.

Third, unlike most existing taxes, carbon taxes are not aimed primarily at raising revenue. Moreover, they do not intentionally create a distortion in the price system but are intended to correct one, though they can create some new, but likely lesser distortions through a tax-interaction effect.

These factors have important implications for the disposition of carbon tax revenues (or revenues from the auction of carbon emission permits) by the implementing authority (country or region), including the possibility of using carbon tax revenues for tax relief that promises to reduce the distortionary nature of the pre-existing tax system. This revenue recycling can take a number of forms (reductions in personal income taxes, corporation income taxes, etc.), with different distributional impacts. Again, however, the final impacts of these alternatives are not a priori obvious when one allows for general equilibrium considerations.

Overall, a large number of other factors, both unique to carbon taxation and applicable to tax policy in general, can have a major bearing on the relative unevenness of impacts (OECD, 1995; Parry et al., 2007). It is also important to note several factors that affect the size of the aggregate impact, since it will also have a bearing on the degree to which the baseline income distribution changes. Of course, the size of the aggregate impact can affect the distribution of impacts in highly nonlinear models or where such factors as income elasticities of demand vary strongly across income groups. Major factors include:

1. Magnitude of the carbon tax or emission permit price, and energy-intensity of the economy. The higher these factors, the larger the overall impact and the more profound income inequalities of impacts can become in relation to the baseline (Hamilton and Cameron, 1994).
2. The unit upon which the tax is based (e.g., energy equivalent, carbon emissions, or carbon content), the narrowness or breadth of products or entities on which that tax is imposed, and the point in the production or consumption process at which the tax is imposed. These bear on the relative bluntness or precision of the policy and hence its cost-effectiveness and overall impacts. For example, Barker and Kohler (1998) found a tax on energy as a whole to be regressive but a tax on motor fuels to be progressive (cf., however, Wiese et al., 1995; West and Williams, 2004)

3. The extent of factor mobility, which determines the degree to which the impacts result in unemployment and capital retirements. For example, Kopp (1992) noted the regressivity of transitional effects on coal miners having to find jobs in other industries.

4. The degree to which the impacts result in unemployment. Those already in lower income groups are less able to withstand the shocks of both temporary and long-term unemployment (OECD, 1995; Fullerton and Heutel, 2005).

5. The extent to which general equilibrium effects are taken into account to capture production/income distribution/consumption interactions in response to the policy (OECD, 1995; Oladosu and Rose, 2007). For example, a large decrease in coal production may have a disproportionate effect on income of high-wage unionized miners, but the decrease in their consumption may be for products that are characterized by a predominant number of low-wage earners, such as food (see, e.g., Rose and Beaumont, 1988).

6. The extent to which dynamic effects are taken into account (e.g., with respect to savings and investment). The current income distribution has an effect on economic growth, which in turn affects future income distribution (Bovenberg et al., 2005). Here progressivity is often thought to have a detrimental effect on future growth, though the effect on future income distribution is ambiguous. Dynamic effects also have a bearing on asset markets, such as the extent to which financial returns are affected and its implications for investments (Harrison, 1994).

7. The use of annual income versus lifetime income as a reference base (e.g., as proxied by consumption). The latter is the more appropriate measure given the long-run nature of the issue (see, e.g., Dinan and Rogers, 2002).

8. The extent to which demographic considerations pertaining to household composition are taken into account (Hamilton and Cameron, 1994); related to this is the demarcation of income groups, especially at the highest and lowest levels (Kopp, 1992).

9. The type of policy instrument used. Free granting of permits is likely to be more regressive than auctioning permits (or implementing a carbon tax) because the former provides assets to owners of capital, while the latter provides opportunities for progressive revenue recycling (Parry et al., 2007)

10. The type of revenue recycling (including lump-sum transfers) and in contrast to alternatives such as budget deficit reduction and individual and corporate tax relief (see, e.g., Goulder et al., 1997; Parry et al., 1999; Parry, 2004). The latter is usually considered the most regressive.

11. Market structure. Regressive effects increase with the ability to shift the tax forward to consumers (Burtraw et al., 2001).

12. Basic parameters and assumptions of the analytical model (especially price elasticities of demand and supply, elasticities of substitution with respect to inputs and imports, market structure, labor supply elasticities, etc.).These factors determine the ability to shift the tax forward onto customers or backward onto factors of production. In terms of the latter, shifts on to labor are likely to be more regressive than shifts onto capital (see, e.g., Boyd et al., 1995; Bovenberg et al., 2005). Also, the greater the variation in price and income elasticities of demand, the greater the potential progressivity or regressivity.

If we try to summarize studies of carbon taxes on households, we find that the distributional effects of a carbon tax can often be regressive unless special circumstances prevail (Bye et al., 2002; Oladosu and Rose, 2007). Consequently, there is likely to be a conflict between efficiency and equity goals, though this can be diminished somewhat if tax revenues are used either directly or indirectly in favor of the low-income groups. Of course, other groups may seek relief as well. Bovenberg and Goulder (2000) have derived a useful result that only a small portion of revenues are needed to leave corporations in the U.S. no worse off.[16]

3.5 Sectoral Impacts

The sectoral impacts of climate mitigation policy depend on several considerations. One is policy instrument choice and design. Free granting of permits imposes a relatively lower burden on emitters, mainly carbon-intensive industry, as would the recycling of carbon taxes to reduce corporate tax rates. Even more significant is the stringency of the emissions cap given the exponential shape of the mitigation cost curve is most sectors.

Instrument choice and design is also a major influence on sectoral differentials. Rose and Oladosu (2002) estimated that a cap and trade system in the U.S. to meet its Kyoto commitment would lead to a permit price of $128 per ton carbon equivalent if it was applied only to carbon mitigation. Allowing for sequestration as well lowered the estimate of the permit price to $43, and adding methane mitigation lowered it further to $33. Under the more narrow policy scope, sectoral output losses in the coal, oil and electric utility industries were projected to be 64%, 25%, and 13%, respectively, compared with 32%, 8%, and 4% for the

[16] Note also, that while the carbon tax approach is usually characterized as comprehensive, it can be partial (as in a partial auction of permits) if some baseline emissions (or fuels in an "upstream" system) are exempted.

most flexible of the three designs. Also, not surprisingly, the agricultural and forestry sector impacts changed form a 3% output loss under the narrow scope to a 1% gain under the broadest scope

Aune et al. (2007) focus on the impacts of climate policies for fossil fuel producers, particularly how different climate policy instruments such as CO_2 taxes and renewable energy subsidies affect the profitability of fossil fuel production, given a fixed global climate target in the long term. They find that CO_2 taxes reduce the short-term profitability to a greater extent than technology subsidies, since the competition from CO_2-free energy sources does not become particularly noticeable until decades later. Most fossil fuel producers therefore prefer subsidies to their competitors above CO_2 taxes. However, this conclusion does not apply to all producers. Oil producers outside OPEC lose the most by the subsidising of CO_2-free energy, while CO_2 taxes only slightly reduce their profits. This is connected to OPEC's role in the oil market, as the cartel chooses to reduce its extraction significantly in the tax scenario. The reason is that OPEC considers the oil price as a decreasing function of its own production. It will then be able to keep up the oil price and therefore its marginal revenue from oil sales by reducing production. Thus, the non-OPEC countries can free ride on this production reduction. The results seem to be consistent with observed behaviour of important players in the climate negotiations, as the OPEC countries and the major coal and gas producing countries will lose most from an international climate policy with short term reduction goals, such as the Kyoto Protocol. These countries have also been major opponents to the treaty.

Sathaye et al. (2007) lists many mitigation measures that improve productivity in nearly all sectors. Also, concern over loss of competitiveness in many sectors may be misplaced. Zhang and Baranzini (2004) reviewed several empirical studies and concluded that energy or carbon taxes do not have a major effect on this concern (see also IPCC, 2001). Still, over time, small changes in competitiveness can add up. Unless carbon capture and sequestration solves its cost and environmental issues, we can anticipate the demise of the coal industry in many countries, and declines are likely in the oil industry. No doubt renewable energy industries will flourish in any case.

Note that mitigation in some sectors promotes various other aspects of equity. For example, Sathaye et al. (2007, p. 726) points out that various agricultural mitigation and sequestration options in developing countries" promote social harmony and gender equality."

4. Equity in international climate negotiations

As global warming is a typical global public good problem, where climate change depends on global emissions of greenhouse gases, there is no reason to expect the problem to be solved without an international agreement, as no country or government has economic incentives to mitigate what may be defined as the socially optimal amount.

Before studying the process and outcome of negotiations, one interesting question is to study an *ethical starting point* for international greenhouse gas negotiations. Eyckmans and Schokkaert (2004) describe what they call an ideal approach or a normative view of greenhouse gas negotiations. The ethical focus is inspired by John Rawls' Difference Principle (Rawls, 1971), and is to concentrate on the poorest people of the world. The top priority of an agreement, according to the authors, should be to raise the living standard of the poor people above the minimum living standard threshold. To do so, one should not ideally concentrate on nations as if they where individuals, as this will not take into account the distribution of income or consequences of global warming within the country. The authors also defend a consequentialist approach, which means that burdens should not necessarily be distributed according to past responsibility for greenhouse gas emissions as is often argued, but to help the extreme poor; the solution should be sensitive to consequences.[17] In addition to this, Eyckmans and Schokkaert take a position against the welfarism embodied in utilitarianism, as this does not take into account the position of the poorest. To raise the poorest people above a minimum threshold implies that they are given greater weight in the calculation of the aggregate than people with a high living standard. This may point in the direction of equity weighting as discussed above, and excludes simple sum ranking, such as maximizing world gross national product (GNP) as the aim of an international treaty.

[17] One counter-example about responsibility offered by the authors is if we discover that a huge global environmental problem is caused by consumption of a commodity heavily concentrated in the poor area of the world. At the time of consumption nobody knew that this would create an environmental problem. Should then the poor world bear the burden of mitigation policies, or should the rich countries bear the largest burden? Eyckmans and Schokkaert (2004) favor the second answer. We follow up the subject of historical responsibility, see Section 5.3 below.

The focus on the poor is particularly relevant as cheap reduction options are mainly found outside OECD, see above. But emission scenarios from IPCC show that business-as-usual emissions in these countries will grow considerably over the next decade (IPCC, 2000). In these scenarios, it is assumed that the developing countries will develop and reduce poverty. Even in the worst case scenario when it comes to economic growth, it is assumed that the average per capita income in developing countries is 12 times higher in 2100 than in 1990. However, to stabilize concentrations of CO_2 at 450 or 550 ppm in 2100, which are often mentioned as stabilization goals, will require a substantial reduction in the emission growth for the developing countries.[18]

Most economic research on international climate negotiations has, however, focused on the *process of negotiations* using game theory (see, e.g., Barrett, 2005, for an overview). In this literature, one common assumption is that each negotiating country only take into account its own material payoff and acts as a selfish agent (i.e., not in line with the framework discussed above). Using non-cooperative game theory, assuming that agreements cannot be binding, analysts define a non-cooperative outcome in greenhouse gas emissions, which is a Nash equilibrium where countries do not cooperate, but takes the other country's actions into account when deciding their emissions. In contrast, a full cooperative outcome is defined as the outcome that maximizes the aggregate payoff to all countries. This outcome is not sustainable, as most countries will benefit from free riding on other countries' emission reductions. The challenge is to improve the non-cooperative outcome or to sustain the full cooperative outcome.

The conclusions from this literature do not seem very optimistic if the aim is to reduce climate change (Barrett, 2005). A self-enforcing agreement, in such a way that no signatory can gain by withdrawing and no non-signatory can gain by acceding is hard to construct and will in general fail to sustain the full cooperative equilibrium. The number of signatories will be small compared to the number of players in the game, or the emission reductions will be small compared to the full cooperative outcome. However, it should be noted that a self enforcing

[18] An interesting equity aspect therefore concerns the choice between economic development and preserving the environment. While this sustainability problem clearly concerns intergenerational equity, it is also a question of equity within one generation; do we have to choose between less poverty and a good environment for people living in 2100, or is a good environment necessary for development? The latest IPCC report (Sathaye et al., 2007) discusses this problem but argues that greenhouse gas emissions "are influenced by but not rigidly linked to economic growth". It further argues that development aid and the Clean Development Mechanism (CDM) may help reduce vulnerability and provide financial resources for development.

agreement does not take fairness into account. Compliance is a further problem, as credibility of punishments is in general small. But, there may be ways to improve the agreement by using side payments as well as linking the environmental negotiations to other non-environmental issues such as international trade (see, e.g., Folmer et al., 1993).

Players may, however, not only care about material benefits. This is for instance studied by Hoel and Schneider (1997), who assumes that there is a cost to deviate from a social norm saying that countries should not free ride. Thus, this is a penalty that increases in the participation of others, and this cost is born by the free riders only. In this way the problem of credible punishments as discussed above are avoided. Not surprisingly, this norm leads to more cooperation. In addition to this, equity arguments have often been seen as a means to facilitate negotiations, as equity principles may serve as focal points that may reduce negotiation costs (Schelling, 1960). Preferences for equity may improve cooperation in international environmental agreements compared to the relatively pessimistic predictions from the traditional economic models (Lange and Vogt, 2003; Lange, 2006). However, this is based on the assumption that countries agree on a single equity criterion. This may not be the case. Lange et al. (2007a), demonstrates the self-serving use of equity principles, meaning that countries put forward the equity principle that serve their interests; support for an equity principle is stronger the less costly it is compared to the alternatives.[19] The bargaining power of the parties may depend on the possibility of using self-serving equity criteria supporting their demands.

This discussion leads us into the field of behavioral economics, which emphasizes that people are not solely motivated by material payoffs and that perceived fairness and social norms influence decisions (see, e.g., Brekke and Johansson-Stenman, 2008). This is relevant as personal communication is important in negotiations and also as Governments may like to implement the preferences of people. Some of the conclusions from this literature are more optimistic when it comes to mitigate climate change and achieve a fair outcome, for instance that people are willing to choose cooperative behavior but only if others are doing so. They are also willing to contribute more to good social causes if they think other people are contributing, and teams seems to act more altruistic than individuals, which may be good news in negotiations where countries are represented by a group of people. Further,

[19] Social preferences may also depend on nationality and culture, see, e.g., the seminal paper of Roth et al. (1991) or Konow (2008) for a recent study.

reciprocity such as punishments is not always motivated by future gains but also of what is considered fair or right, which may make punishments more credible. But on the other hand, people's behavior does not always support fair outcomes. What is perceived as fair is often influenced by self interest, as mentioned above, and we like to avoid situations and information that would force us to reflect over ethical issues if this is in conflict with our material interests (Nyborg, 2008).

The last step in international climate agreements is for signatories to choose their emission levels, i.e., the *outcome of the agreement*. If countries are symmetric, i.e., equal, it is usually assumed that signatories choose their emission levels to maximize the total payoff, which again requires equal provisions or emission reductions. For asymmetric or heterogeneous countries, other solution concepts are studies such as the Nash bargaining solution where gains are distributed according to bargaining power, the core focusing on the grand coalition of all countries where no coalition of countries can gain by rejecting the proposal, and the Shapley value where the gain is distributed by side payments that average each player's marginal contribution to the different coalitions that might form (Barrett, 2005). These concepts do not explicitly take into account fairness, and illustrates that there may be a conflict between equity and efficiency considerations. This leads us into the discussion of implementing climate agreements using price incentives.

5. Implementing climate agreements using price incentives

5.1 Carbon taxes

To find the efficient abatement level in each country, the standard economic recommendation is to use Pigouvian taxes on the harmful emissions. Optimizing a global welfare function would require that the tax should be set so that it reflects the marginal social damage of greenhouse gas emissions. Alternatively, the tax should be set so that the emission target from a climate agreement is met. In the first best optimum, this would lead to a uniform tax of all polluters, i.e. across sectors and countries. Thus, the optimal carbon tax should be globally uniform. This is also the recommendation in the Stern Review (Stern, 2007).

This result was first criticized by Eyckmans et al. (1993) and Chichilnisky and Heal (1994). They study the outcome of maximizing a social welfare function, where fairness can be taken into account by welfare weights. The result from this optimization problem is that weighted

marginal abatement costs should be equalized across all countries. This challenges the traditional view that marginal costs of abatement across countries should be equalized to achieve efficiency. If the weighted marginal utility of consumption of the private good is higher in poor countries than in rich, marginal abatement costs should be lower in poor countries than in rich. However, the papers demonstrate that if side payments (lump sum transfers) are made available, a cost-effective solution in the traditional sense may be restored. This would require substantial transfers from rich to poor countries. Based on this, Sheeran (2006) notes that international transfers to developing countries are necessary for efficiency, even if these are usually favored on equity grounds.

Another critique of the standard results follows from the realism of the assumptions. A first best solution is characterized by no constraints on the use of policy instruments. Lump sum transfers are for instance included in the set of feasible polices. If these assumptions are not met, the standard result of a uniform global carbon tax must be reconsidered, see, e.g., Sandmo (2007). Consider, e.g., two countries, one rich and one poor. If lump sum transfers are not possible, and if the global social welfare function is egalitarian, the tax in the poor country should be lower than in the rich. This means that the poor country can devote more resources to the production of private goods and less to the public good (the environment) and this will therefore work as an income transfer from the rich country to the poor. Note that this will not separate efficiency and justice considerations. Non-uniform taxes have the cost of lower production efficiency, but will still increase the global social welfare under the assumptions above. Sandmo (2005) provides a discussion on the implications of this result for a world of many countries. Instead of introducing country-specific tax rates, one possibility is to introduce a small number of tax-rates and applying them to groups of countries.

5.2 Reluctance to trade emission permits and moral motivation

One alternative to carbon taxes are tradable emission permits. Under the ideal assumptions mentioned above, tradable emissions permits will lead to the same outcome as a uniform carbon tax. The polluters will face a uniform price of polluting, which will foster the traditional cost efficiency in environmental policy making (see, e.g., Montgomery, 1972; Schmalensee et al., 1998).

However, permit trading has been opposed by many such as environmental organizations and political parties on other grounds than rejecting the ideal assumptions. Some consider trade in

pollution permits as a way to try to avoid one's obligations, to pay others to clean up, or to pay indulgence, see the discussion of environmental justice above and Goodin (1994). In the Kyoto protocol, trade in pollution permits is allowed, but only as a supplement to national mitigation.[20] This mechanism may have been introduced as a consequence of the majority of the signatories being reluctant about permit trading. Also in the European Emission Trading Scheme (ETS) proposals have been raised to limit the access to buy emission reductions in third party countries (JI – Joint Implementation for economies in transition and CDM - Clean Development Mechanism for developing countries) in the third phase (2013-2020). Why is there reluctance to trade in certain goods such as pollution permits?[21]

There have been some arguments against trade in emission permits based on consequences (consequentialist equity), such as adverse effects of CDM (e.g., it may create bad incentives such as to overstate the emission reductions from a project) and Hot Air (some countries get initial emission quotas that are higher than their actual emissions, thus the effect on the environment is small) and loss of potential national benefit from a pollution permit system (e.g., positive spillovers of technology development and ancillary benefits) and environmental justice. However, based on procedural equity, it is not enough to know that the action is the most effective way to attain the aim. One can for instance argue that industrialized countries have created the global warming problem, and that is their duty to reduce the consequences of it by cleaning up their own backyard, even if this is does not minimizes overall abatement costs. Another argument is based on unfair background conditions. Even if two parties agree to trade permits, the trade may not be justified on ethical reasons. A voluntary agreement between two parties is not necessarily fair if it is entered into under conditions that are not fair (Pogge, 1989). Background justice is not preserved when some participant's basic rights, opportunities or economic positions are grossly inferior.

Eyckmans and Kverndokk (2008) investigate how moral considerations, modeled as preservation of identity, i.e., a person's self image - as an individual or as a part of a group (Akerlof and Kranton, 2000, 2005), affect an endogenous pollution permit trading equilibrium, in which governments choose in a non-cooperative way the amount of permits they allocate to their domestic industries, i.e., aggregate emissions are determined in the

[20] However, attempts to implement a strict supplementarity requirement, such as limiting permit purchases to 50% of GHG reduction requirements, have failed.
[21] For a recent survey on distaste or repugnance for certain transactions, see Roth (2007).

equilibrium. They show that governments' moral concerns may actually increase global emissions but this result depends on the precise formulation of the identity function, i.e., how identity is specified. For instance if potential permit importers feel reluctant to buy permits, global emissions will be higher than in an endogenous permit trading equilibrium without moral concerns. The reason is that permit importers over-allocate their domestic firms in order to reap strategic permit trade gains (because of lower global permit prices) and to reduce the amount of permits they have to import and hence their loss of identity. However, if there is also reluctance to sell permits, the opposite effect may take place and global emissions might be lower than compared to the case without moral concerns. Finally, if identity depends on the gap between actual and ideal emission levels, i.e., a higher gap means lower identity, and where the first-best Pareto efficient emission allocation is defined as the ideal (see Brekke et al., 2003), global emissions will always be lower when moral concerns are present.

Both tradable emission permits and carbon taxes are policy instruments working through price incentives. There is now a growing literature on how price incentives interact with moral motivation and considerations. First, price incentives such as taxes may crowd out moral motivation to contribute to a public good such as a good environment as it may change the responsibility of the problem from the individual to the regulating authority (Frey, 1997; Brekke et al., 2003), so the net effect may be low. However, reciprocity, which means that people reward kind actions and punish unkind actions, may work the other way (Rabin, 1993; Camerer, 2003). If people know that polluters are punished they may be willing to contribute more too. Finally, if people are concerned about social norms, i.e., a rule of behavior that is enforced by social sanctions, public policy may have large effects. In general models of social norms give multiple equilibria (Nyborg and Rege, 2003; Rege, 2004); the more people that follow the norm, the higher are the sanctions and new information may move the society from one equilibrium to another. A carbon tax may for instance give information about the severity of climate change as this is a sign that the Government takes climate change seriously, and, therefore, change the social norm and bring the society to a new equilibrium where people act more environmental friendly than before.

5.3 The allocation of emission permits

In Eyckmans and Kverndokk (2008) discussed above, it was assumed that before emission trading, governments choose in a non-cooperative way the amount of permits they allocate to

their domestic industries.[22] In this way, the total emission reduction depends on the allocation of permits. This resembles closely the reality of international climate negotiations so far, in particular in the run up to the 1997 Kyoto Protocol and in the coming negotiations on a follow up agreement for the post-Kyoto period, as well as the EU's emission trading system (ETS).[23]

However, it has been argued that if the total emission reduction is set independently of the distribution of tradable emission permits, a system of tradable permits makes it possible to separate efficiency and justice considerations, given that the outcome of the trade is considered equitable. Under the assumption of a competitive market, cost-effectiveness will result from trade no matter how permits initially are distributed (Montgomery, 1972), see also the discussion of the Coase Theorem in Section 2.2.[24] Based on this, the initial distribution of permits can be discussed as an intragenerational distributive justice problem as it concerns the distribution of income within the current generation.[25]

This view is challenged by the result in Eyckmans et al. (1993) and Chichilnisky and Heal (1994), as referred above, that weighted marginal costs and not the marginal costs of abatement should be equalized across countries. These results have implications for tradable emission permits and Chichilnisky and Heal (1994) suggest that one may need to look at a Lindahl equilibrium rather than a Walrasian equilibrium in tradable permits, as a Lindahl equilibrium assigns a different price for the public good for each agent (region) based on his/her willingness to pay. This is followed up in Chichilnisky et al. (2000) who also show that in the absence of Lindahl prices, only a final number of initial permit allocations can lead to efficiency. Thus, the traditional result that efficiency and equity matters may be separated with tradable emission permits does not necessarily hold.

However, several studies have looked at how distributive justice should ideally be taken into account in the allocation of tradable emission permits. Below we present three views.

[22] This modeling framework was first suggested in Helm (2003).
[23] The amount of emissions permits brought under the EU cap is not fixed.
[24] Market power may be a problem in the international permit market (see, e.g., Hagem and Westskog, 1998, 2008). Concerns have been raised that market power may arise that would skew the distribution of permit revenues in favor of one or a group of countries (e.g., Eastern European countries as they are the largest sellers). Given the size of the international permit trading market and number of potential players, this is unlikely to be a major concern at that level. However, it may matter in some interregional trading initiatives.
[25] This assumed that there is separability of intergenerational and intragenerational justice.

Kverndokk (1995) was one of the first to evaluate different permit allocations for carbon dioxide (CO_2) emissions permits based on theories of distributive justice. To do this, he proposed one way to solve this problem, namely by using the meta-principles introduced in Section 2.4 above, that is ethical individualism and presentism, together with a generally accepted principle in global theories of justice of avoiding distributions based on moral arbitrariness, i.e. on morally arbitrary factors, factors that are not relevant for the distribution problem. An analysis using these principles of justice requires a list of competing allocation rules, since we can say which rules from a given list violate the principles, but we cannot determine the "best" allocation rule. Thus, the following simple allocation rules were evaluated:

- A distribution proportional to current CO_2 emissions.
- A distribution inversely proportional to accumulated CO_2 emissions.
- A distribution proportional to Gross Domestic Product (GDP) or to GDP adjusted by purchasing power parities.
- A distribution proportional to land area.
- A distribution proportional to population.

According to the analysis in Kverndokk (1995), a distribution of permits proportional to population (equal per capita criteria) appears to be the only rule from the list of alternative allocation rules that is in accordance with all the three principles of justice. However, this would require substantial transfers from rich to poor countries (see, e.g., Rose et al., 1998).

Neumayer (2000) also agrees on an equal per capita basis for allocating emission rights, but he argues in favor of historical accountability, i.e., every human is given an equal share of the global resource atmosphere independent of place and time. He defines the term Historical Emission Debt (HED), which measures how much countries have emitted compared to their share of world population from the start year, where depreciation of greenhouse gases in the atmosphere is taken into account. Countries with a positive HED has to compensate countries with a negative HED in the annual permit allocations. Neumayer has three arguments in favor of historical accountability. First, science supports this rule as climate change is a consequence of the increased concentration of greenhouse gases in the atmosphere, which is a function of accumulated emissions. Second, historical accountability is consistent with the

polluter-pays-principle, which is a well established principle within the OECD countries (OECD, 1974). Finally, historical accountability is supported by the principle of equality of opportunity (Rawls), i.e., everybody should have an equal opportunity to benefit from emissions. Neumayer argues against several objections to this allocation rule, such as past generations were ignorant and the developed countries should therefore not be held responsible, that present generations must not be held accountable for something that was not caused by themselves, positive spillover effects from the emitting to the non-emitting countries, practical reasons such as boundary changes and massive economic costs, and finally, that historical accountability is closely correlated with current emissions.

Helm and Simonis (2001) also agree that the equitable distribution of the initial endowment of emission permits should be based on the equal per capita criteria, but have not addressed the problem of accounting for historical emissions. However, they argue that this is only a "local" equity problem (see Section 2.4 above), and that the "global" equity problem is to develop criteria for a just exchange or trade of the initial endowment of permits. The authors suggest the following criteria for this exchange to be equitable, based on the idea that the use of the common resource (the atmosphere) should exhibit a certain degree of solidarity:

- *Pareto efficiency*: There should be no reallocations that make someone better off without making anyone worse off, i.e., there should be an efficient final allocation of permits.
- *Envy-freeness*: Every agent should (weakly) prefer his own share of the common resource and compensatory payments to the share of any other agent.
- *Individual rationality (lower bound)*: No agent should be made worse off by the trade in emission rights than he was beforehand. This means that compensation should be equal to abatement costs.
- *Stand-alone criterion (upper bound)*: No agent should be made better off than he would be if he were able to use the whole resource on his own. This means that no country should receive compensation higher than the abatement costs it would save with the quantity of global emissions rights, i.e., without any abatement efforts.

Based on the two latter criteria, the North (developed countries) would have to offset all of the South's (developing countries) abatement costs, but the South should not demand any

additional transfers and would have to consent to reduction measures required for reasons of efficiency (the first criterion). This solution will also be envy-free (the second criterion).

If the reallocation of initial entitlements based on equal per capita emission is governed by competitive markets, the market driven final allocation of permits will violate the stand-alone criterion as developing countries will be better off than without any environmental restrictions. The authors suggest another mechanism where all countries are assured the minimum resulting from competitive allocation and stand-alone utility, called the "WESA mechanism"[26] that will meet all four criteria above. Based on this, the authors claim that we will achieve both local and global equity if the permits are initially distributed according to an equal per capita allocation and the WESA mechanism is used for the exchange of permits.[27] However, if competitive markets are used without any restrictions, this would require a different initial allocation rule to meet the criteria above. Helm and Simonis (2001) show that developing countries then would be given less and developed countries more than the equal per capita distribution initially to meet the stand-alone criterion. But the difference from the equal per capita distribution will diminish over time due to the high growth rates in greenhouse gas emissions in developing countries. This allocation rule resembles the initial allocation rule suggested by Cline (1992), where permits are allocated according to current emission levels initially and then converge into an equal per capita distribution over time (or what has become known as the "contraction and convergence principle").

The outcome of the trade or the exchange is, however, dependent on how emissions of a country are measured. This opens a discussion on how to assign responsibility for greenhouse gas emissions. The traditional approach is to assign responsibility for emissions from your geographical area, so that emissions from production processes in a country like Norway are assigned to Norway independent of its consumption (production accounting principle). This is the approach used in the Kyoto Protocol (see also IPCC, 1996). With this approach, a country may have a high living standard and relatively low emissions if it imports all its carbon intensive goods. An alternative is consumer responsibility, which is to assign emission responsibility for all emissions that follow from the process that finally ends in consumption

[26] WESA = Walrasian mechanism with the stand-alone utility as an upper bound. Thus, this refers to a market driven equilibrium outcome with restrictions.
[27] For a new study that is also concerned about the fair exchange of permits, see Böhringer and Helm (2008). They provide simulation results from a computable general equilibrium model with an upper welfare bound that restricts the income from selling permits.

(see, e.g., Ferng, 2003).[28] In this way, a country's living standard would be more closely connected to its emissions.[29] There are pros and contras for both approaches. The production accounting principle gives incentives for cleaner and more energy efficient production process (including technology development), but also incentives to transfer dirty production to the developing world or countries that have not signed a climate treaty (carbon leakages). The reverse will be the case for the consumption accounting principle. A consequence of the latter principle would probably be that developing countries are assigned lower levels of greenhouse gas emissions, while the developed world would be assigned a higher level. Bastianoni et al. (2004) argues for a principle that represents an intermediate approach, where greenhouse gas emissions (GHG) should be "assigned to countries or phases of the process in proportion to the embodied GHG emissions needed along the chain".

What should be considered the fair approach for assigning responsibility for emissions? Bastianoni et al. (2004) argue that the consumption accounting principle is fairer than the production accounting principle because it would make final users pay for the greenhouse gas "bill". However, production processes are also beneficial for producing countries, and typical examples of this are countries producing and exporting products based on natural resources (oil, gas, fish, and water power). Thus, we think this issue has to be discussed further from an ethical perspective.

6. What equity principles have actually been used?

Cazorla and Toman (2001) have pointed out that a single or compound formula, involving a combination of equity considerations, is unlikely to satisfy the self-interest of the majority of the industrialized and developing countries to obtain a truly international agreement. It could also be said that such a formula might not satisfy a consensus of countries in terms of pure equity considerations either. Cazorla and Toman suggest that the "dynamic graduation" formulas, such "contraction and convergence" (Jacoby et al., 1998; Meyer, 2000), nicely balance short-term and long-term interests of all parties (see also the approach recommended by Nordhaus, 1997).

Victor (1999) has claimed that equity has had little influence on negotiating and implementing international agreements on climate change. In the case of the Kyoto Protocol, for example,

[28] This is related to the literature on the Ecological Footprint, see, e.g., Wackernagel and Rees (1996).
[29] A third possibility could be to assign responsibility for production of fossil fuels.

Victor (2001) suggests that self interest will continue to dominate uncertainties about future emission trajectories and thus make it difficult to identify equitable permit allocations, and that, in the end, compliance will not be forth coming if it is not in a country's self interest. A recent compendium of papers on the Post-Kyoto World edited by Aldy and Stavins (2007) also give short shrift to equity. However, Lange et al. (2007b) performed a statistical analysis of survey responses of people involved in international negotiations and concluded that equity was considered important, with a stronger preference being expressed by members of G77 countries. The most favored principles overall of the small set of six examined are polluter pays, egalitarian, and "poor losers" (basically analogous to the Rawlsian Maximin). Ringius et al. (2002) concluded that appeals to fairness make it more likely that agreement will be reached, and, based on an analysis of the proposals presented by several countries in the run-up to Kyoto, have identified a set of such principles that are widely accepted—equality, equity and exemptions for parties who lack the capacity to contribute. Still, this begs the question of whether negotiators can agree on specific principles for allocating the burden of GHG mitigation.

Despite the extensive examination of equity by analysts and bargaining by policy makers, its application in climate change policy at all levels has been rather unsophisticated. Only a couple of traditional principles, as well as a few pragmatic allocation rules based on political compromise, have dominated. For example, the prevailing principle has been what we termed "Sovereignty" in Table 1 — equal proportional emissions reductions by all parties. Because both mitigation costs and benefits are unequally distributed, this is inconsistent with all other allocation-based and outcome-based principles. It might appear that, because it is the outcome of negotiations, it is consistent with process-based allocations in general and consensus equity in particular, but this smacks of circular reasoning.

The prime example of using Sovereignty equity based on GHG emissions is the Kyoto Accord, where any departure from the rough group average emission cap had to be justified by "differentiated responsibilities," based on special conditions in an individual country. Thus, transitional economies, such as Russia, were allowed lower commitments because of their economic difficulties, despite the fact that their economic downturns would lead to lower emissions in the future anyway, thus exacerbating the "hot air" problem. Other special circumstances included Australia's emissions cap of 108% of its 1990 baseline (in

comparison to the group average of approximately 93% of 1990 levels) because of its heavy reliance on coal exports. Note that differentiation was not put forth expressly as an equity principle but as an ad hoc appeal to special circumstances. The industrialized countries were wary of using equity as an explicit argument, because they were concerned the argument could be turned against them by more than 100 developing countries (DCs) at some time in the future.

Similar proportional emission cutbacks pervaded the major regional climate agreement in the U.S.—the Regional Greenhouse Gas Initiative (RGGI) among Northeast and Mid-Atlantic states. More recently, however, as the target date nears and concerns about compliance costs increase, discussions have arisen about target levels and relative positions of individual states.[30] Based on this experience, those beginning to negotiate a GHG trading arrangement in the Western States in the U.S., the Western Climate Initiative (WCI), are beginning to look at equity head-on. Their first foray at the time of this writing is a mixed formula for future emissions growth that involves a weighted average of proportional cutbacks, energy use, and population. Still, the focus is on simple reference bases, rather than a deeper discussion of equity. Moreover, the mixed formula represents more of a way of achieving group consensus and finesses the hard choice of a single criterion.

The major area in which equity is now critical and under which much activity is underway is in bringing DCs into the fold in terms of actual mitigation commitments, or simply involvement in flexibility mechanisms beyond CDM. One equity formula that has been popular for years and holds the prospect of easing some of the tensions regarding the egalitarian principle is "contraction and convergence" (see, e.g., Cline, 1992) This calls for proportional cutbacks of emissions with respect to a baseline level among individual countries now but with eventual adjustment over time to a point where emission permits would be assigned on a per capita basis. It is believed that the 20-30 year convergence target date would give industrialized countries time to adjust so that the large future emission reductions or permit purchases would not be anywhere near as costly as would be the implementation of the egalitarian principle during the first, or even second, Kyoto compliance period (Jacoby et al., 1999).

[30] Several of the RGGI states have decided to auction rather than grandfather their permits and to use the revenues to promote energy efficiency including effectively lowering energy prices and targeting low-income households for energy efficiency investments (State of Maine, 2007).

The second approach is the "no harm" principle (see Edmonds et al., 1995), which calls for an allocation of permits that would result in no net positive costs for DCs. Rose et al. (1998) have pointed out that this is essentially a variant of a welfarist version of the Rawlsian Maximin principle.[31] In any case, there are two interpretations of the no-harm rule. The first is to give DCs permits equal to their baseline emissions. The advantage is that it means they have a sufficient number of permits such that no mitigation is necessary, nor is it necessary for them to be involved in the permit market initially. However, once they are comfortable with doing so, it is hoped that DCs would see the advantage of selling permits to gain revenues. When they do so, industrialized countries will gain by having their compliance significantly lowered by access to relatively cheaper mitigation/sequestration options. The second variant of the no-harm rule calls for permit allocations for DCs such that, after trading, they incur no net costs, i.e., any revenue gains from trading are limited because permit allocations are set below baseline levels. In this case, DCs incur no net costs and industrialized countries, which will still incur positive net costs, are still helped by access to relatively cheaper options. Note that the first variant is an "allocation-based" principle, where individual country permit levels are determined at the outset. The second is an "outcome-based" rule that considers the results of the post-trading stage. The first involves less uncertainty than the second because it is not based on an unknown second step. The uncertainty, however, can be reduced by a central authority ensuring a zero net cost outcome through financial transfers out of a common pool, whose funds might be provided by industrialized countries or by any excess revenues (over zero net cost) from the group of DCs.[32] In the second case, DCs are more likely to be engaged in permit trading because the initial permit allocation requires them to undertake mitigation, and they will be looking for ways to reduce compliance costs. Rose and Wei (2008) have simulated the implications of these two permit allocations for Pacific Rim countries and found that the first allocation variant would result in significant gains for China and other developing countries, while, of course, the second would have a neutral effect on them. Interestingly, the largest absolute gains in either case are projected to go to industrialized countries, most notably Japan.

[31] We have listed the Rawlsian Maximin principle in the group of outcome-based equity criteria in Table 1. However, many would argue that Rawls was not so much interested in the outcome as in the process.
[32] Of course the practicality of such an arrangement is open to question.

7. Equity and uncertainty - are emission reductions really necessary or are there other ways?

To significantly reduce the accumulation of greenhouse gases in the atmosphere, broad international cooperation is required. As discussed in Section 4, the literature is not very optimistic when it comes to a broad international agreement on emission reductions, due to the incentives to free ride. However, other approaches to reduce climate change have been proposed over the last couple of decades. One alternative is geoengineering, which seems to be a taboo in the debate on climate policy, and most economic analyses of climate change have ignored it.[33] Geoengineering does not have a singular definition, but we follow Barrett (2008) who refers to measures that counteract climate change by reducing the amount of solar radiation that strikes the earth.[34] Examples of this are installation of a barrier to sunlight between the earth and the sun, placing various particles or gases in the atmosphere to block incoming sunlight, or to make low-level clouds from sea water that also would reflect incoming sunlight. While geoengineering will not reduce the concentration of greenhouse gases in the atmosphere, it will decouple temperature from the atmospheric concentration. Still, a host of known problems, such as increasing ocean acidification, as well as many unknowns, remain.

IPCC regards geoengineering as "largely speculative and may have a risk of unknown side effects" (Barker et al., 2007). However, there are reasons to believe that such measures will become higher on the political agenda in the future. In contrast to emission reductions, some of the proposals are inexpensive and can, thus, be undertaken by a single country unilaterally (Barrett, 2008).[35] Thus, in contrast to agreements on emission reduction, where it is hard to create incentives to sign an agreement, here countries have an incentive to do this unilaterally or as a part of a small coalition.

There are several ethical aspects connected to geoengineering that are not fully discussed. One aspect of procedural ethics is to what extent we should change the functioning of the nature. We are in a process of changing the climate on the earth due to our emissions of greenhouse gases. Is changing the climate due to bioengineering any different? Consider for

[33] An early discussion is Schelling (1996).
[34] Other alternatives are iron or nitrogen fertilization of the oceans, see Barker et al. (2007). They may also be classified as geoengineering, but we choose to follow Barret's (2008) definition.
[35] It has yet to be discussed whether unilateral action is in accordance with international law.

instance the possibility to reduce solar radiation by emitting particles in the atmosphere. This already happens naturally from volcanic eruptions. Also, human activities due to burning of coal for instance emit sulfate particles in the atmosphere. What is the difference between these and particles we purposefully might place in the atmosphere to block sunlight? Can theories of justice guide us on this? Why is geoengineering actually considered a taboo in climate policy; is this due to the ethical concerns or just related to risk? An aspect of distributional justice has to do with winners and losers of geoengineering. How should we account for the fact that this measure will affect countries differently?

Recently the debate over whether it is best to strongly mitigate GHGs or to be less stringent and simply adapt to the climate changes has accelerated.[36] Burden sharing for poor country adaptation to climate change gives rise to issues very similar to those discussed with respect to mitigation (Tol, 2005). However, the argument for adaptation is often facile and ignores irreversibilities, as well as the fact that prior success of human adaptation took hundreds, if not thousands, of years, and not merely decades. Since we are unlikely to actually reduce concentrations of GHGs in the atmosphere in the foreseeable future, but just to slow their build-up, some adaptation will be necessary. Studies indicate that the poor, aged, and infirm are the least likely to cope. Women, who are typically lower paid, and who have a relatively greater responsibility for child rearing are also likely to find adaptation relatively more difficult because of their lower levels of resources and time, as well as more limited choices (IPCC, 2001). At the international level, the areas that are likely to be the most affected—low-lying areas in general and the belt around the equator, i.e., the relatively poorer areas—are also the ones that have the fewest resources to adapt. The Darwinian dictum of "survival of the fittest" rings hollow from an equity standpoint. However, as we need both mitigation and adaptation, we would welcome a better understanding of what is a fair international sharing of the burden for developing and deploying adaptation strategies (see Paavola and Adger, 2005, for a first approach).

The problems mentioned here on uncertainty and risk also link to the precautionary principle (see, e.g., O'Riordan and Cameron, 1995) and the issues about the quality of life for future

[36] There also exists a climate adaptation fund with the aim to help protect those most vulnerable to the adverse effects of climate change, like drought, flooding and severe storms. The fund is managed by the Global Environment Facility, an independent financial organization, and was established in Kyoto in 1997, but has been criticized for being too difficult to access and for raising only paltry sums of money. Under an agreement reached by delegates at the UNCCC Bali conference in 2007, the adaptation fund is now to be maintained using a 2 percent tax on transactions within the Clean Development Mechanism.

generations. Thus, the approaches discussed in this section have clear intergenerational aspects as well.

8. Conclusions

Equity cannot be ignored in climate change policy like it is in so many other policy realms. The fact that the problem is a global one and that the most-effective solutions require cooperation among sovereign entities means that fairness must be taken into account for reasons of positive economics even if there is a tendency to avoid the normative. Many principles of equity that are applicable at the interpersonal level translate nicely to the international and interregional levels and can serve as the basis of sound normative judgments.

Interestingly, most climate agreements thus far have finessed some difficult equity issues. In the international domain, GHG mitigation targets have mainly been agreed to by industrialized countries, meaning those with the means to undertake them without seriously comprising their rates of economic growth. Variations in the commitments have been addressed with the euphemism of "differentiated responsibilities," a type of equity argument that appears easier to swallow. Similar situations of a limited range of diversity of interests have arisen in the regional trading initiative of the Europe Union and in relatively homogenous areas of the U.S. The difficult equity conflicts are still to be resolved, however, primarily getting developing countries, some of which are becoming the most prominent GHG emitters, to agree to significant mitigation targets and timetables.

Research has helped advance climate policy on both efficiency and equity fronts. Cap and trade, under a broad set of conditions (auctioning versus free-granting, unrestricted prices versus price caps, current allocations versus banking/borrowing) has the ability to reduce emissions at least cost and to also address equity head on through the allocation of permits. While researchers have not solved the puzzle of identifying the best definition of equity, they have provided operational definitions and practical models that can be used by policy-makers to identify the implications of various alternatives.

Although the main focus of equity in climate policy thus far has been across geographic areas, it is the individual level where equity is really measured. Traditional fiscal incidence analysis

can readily be applied to the cost side of the equation, but equity on the benefit side represents the real challenge as potential catastrophic impacts of inaction continue to be identified.

We have mentioned several topics in this paper where equity issues are not fully analyzed yet. As equity is important in social and political relations, we would also welcome more studies in economics where moral and ethical considerations are taken into account by the decision makers. People do not always act as Homo Economicus (Thaler, 2000), and economic models that take preferences for equity into account are important in the entire discipline of economics including environmental economics.

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TABLE 1. ALTERNATIVE EQUITY CRITERIA FOR GREENHOUSE GAS MITIGATION POLICY

Criterion	Basic Definition	General Operational Rule	Operational Rule for CO_2 Permits
Allocation-Based			
Sovereignty	All countries have an equal right to pollute and to be protected from pollution	Cut back emissions in a proportional manner across all countries	Distribute permits in proportion to emissions, energy-use, land area, etc.
Egalitarian	All people have an equal right to pollute and to be protected from pollution	Allow emissions in proportion to population	Distribute permits in proportion to population
Ability to Pay	Mitigation costs should vary directly with economic well-being	Richer countries should shoulder a higher proportion of gross cost of abatement	Distribute permits inversely to GDP
Econ Activity	All countries should be allowed to maintain their standard of living	Richer countries should not be penalized	Distribute permits in proportion to GDP
Outcome-Based			
Horizontal	All countries should be treated equally in terms of changes in welfare	Equalize net welfare change across countries (net loss as proportion of GDP equal for each country)[a]	Distribute permits to equalize net welfare change (net loss as proportion of GDP equal for each country)[a]
Vertical	Welfare gains should vary inversely with economic well-being; welfare losses should vary directly with GDP	Progressively share net welfare change across countries (net loss proportions directly correlated with per capitaGDP)[a]	Progressively distribute permits (net loss proportions directly correlated with per capita GDP)[a]
Compensation	No country should be made worse off	Compensate net losing countries	Distribute permits so no country suffers a net loss of welfare
Process-Based			
Rawls' Maximin	The welfare of the worst-off country should be maximized	Maximize the net benefit to the poorest countries	Distribute largest proportion of net welfare gain to poorest countries

Consensus	The negotiation process is fair	Seek a political solution promoting stability of the agreement	Distribute permits in a manner that satisfies the (power weighted) majority
Market Justice	The market is fair	Make greater use of market (auction)	Distribute permits to the highest bidder

Source: Adapted from Rose (19920 and Rose et al. (1998)

[a]Net welfare change is equal to the sum of mitigation costs + permit sales revenues - permit purchase expenditures.

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