Using a model of alternative emissions rights to build a consensus for a just and effective greenhouse treaty.

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Abstract

Negotiating a greenhouse gas reduction treaty that is both effective in stabilizing atmospheric GHG concentrations and is perceived as fair by all nations is an enormous challenge. It seems unavoidable that reducing GHGs will require an overall constraint of consumption, and that ethical considerations of both ability to pay and responsibility for past emissions will require substantial transfer of resources from rich to poor nations. These conditions set up an inevitable conflict as the governments and citizens of the rich nations are forced to make sacrifices for the benefit of poorer nations as well as of future generations of all nations.

Any successful negotiation depends on this sacrifice being accepted, and will require a change in the rich nations (particularly the US) from a conception of unlimited right to consume whatever we can afford, to a conception of limited rights to a global commons. To facilitate discussion of these issues, we build a simple model that links emissions processes (as a function of population, consumption, and technology) and alternative assignments of emissions rights with welfare indices, using selected nations and regions. We demonstrate initial results of alternative assignments of *per capita* emissions rights vs. historically based

national emissions rights, and also explore ways in which such a model may deployed in the public sphere to foster the necessary discussions.

Introduction

The increasing concentration of atmospheric greenhouse gases (GHGs), especially $C0_2$, presents a crucial test of the responsiveness of our current political-economic system to the imperatives of sustainability. While there are legitimate debates over the evidence of an existing anthropogenic impact on global average temperature, we do not address them; rather we start with the widely accepted evidence of significant anthropogenic increases in atmospheric GHG concentrations, and the equally widely accepted conclusion that continuing unrestricted increases will at some point cause dangerous changes to the climate regime (Houghton *et al.* 1996). Among the broad majority of scientists, policymakers and others who accept this conclusion, there exists a wide range of views about the urgency of the problem and the steps necessary to address it. But there is general agreement that in the long run some mechanism for substantially restraining GHG emissions will be required.

This perceived necessity for restrictions on GHG emissions raises fundamental ethical questions about the equitable allocation of resources between and among generations. In order to more explicitly consider some of these ethical issues, in a tool that can potentially be applied in academic, policy, and public contexts, we have developed our own simple model. Its unique aspect is the explicit integration of ethical premises regarding equity, in particular through the assignment of alternative property rights to global emissions and the ability to use different normative evaluations of the distribution of impacts. In reflection of these characteristics, we have christened the model the "Greenhouse Limitation Equity Assessment Model", or GLEAM. In the remainder of this paper, we review some relevant work which our model responds to and/or borrows from, lay out a set of objectives to which our modeling effort aspires, present the model and results of two scenarios, and address further development of this model and its possible use in the policy and public education process. [1]

Climate Change, science, and policy

We envision a global society in which the unequal cultural and economic power of a Western (or Westernized) elite is transformed into a truly democratic and pluralistic international community. Part of this transformation involves changes in the institutions we know today as "science." Many authors have addressed the role modern science plays in shaping structures of power, and the deeper links between the scientific worldview and

[1] The model we use is being developed as a Master's thesis project by the first author with the guidance of the second author, who is his advisor. Model details and code are available from the corresponding author.

today's individualistic, consumer-oriented culture;[2] we take this critique of science as a starting point.

Climate change is a paradigmatic example of the type of problem that Funtowicz and Ravetz put in the realm of "post-normal science": stakes are high, uncertainties are large, and values are essential to the discourse and the solution (Funtowicz and Ravetz 1991). Discussion of climate change requires scientific input of a variety of types, and that various scientific disciplines work together; it also requires that the scientific community take seriously its engagement with policy-makers and the public. One response within the scientific community to this challenge has been the development of so-called "Integrated Assessments."

There are two common ways in which the term "Integrated Assessment" is currently used. The first is as a definition of a fairly specific modeling methodology, particularly in the field of global climate change, in which models from different scientific disciplines are brought together in a simplified numerical form, particularly to link climate processes to economic and social processes.[3] These models are sometimes referred to as Integrated Assessment Models (IAMs). The second definition of Integrated Assessment is as a highly normative, process oriented, generalizable methodology, in which concepts of democratic stakeholder participation and adaptive management are highlighted.[4]

The tension between these definitions is related to alternative conceptions of the role of scientists in the public policy process. The latter definition, to which we subscribe, is one which emphasizes the potential conflicts among social groups, and views scientists as stakeholders with their own interests; the former, rooted in the historical modeling of social sciences after the "objective" natural sciences, strives to remove the author as an interested actor and attempts to define "value-free" models and processes.

A significant amount of work coming from traditional economic disciplines addresses global climate change from this "objective" perspective; in particular, cost-benefit analysis and game-theoretic modeling are often used on their own or brought into IAMs to be linked with climate processes borrowed from simplified climate models. An influential case in the global climate change literature is that of the DICE and RICE models of William Nordhaus and his colleagues (Nordhaus 1994; Nordhaus and Yang 1996), which provide a major frame of reference for US policy makers.[5]

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[2] See for example various works of Jurgen Habermas, Michael Redclift, Richard Norgaard, Jerome Ravetz and Sylvio Funtowicz.

[3] For a discussion of Integrated Assessments of this general type see for example Hasselmann (1997) or Weyant *et al.* (1996).

[4] For example, the SCOPE project on Integrated, Adaptive, Ecological Economic Modeling and Assessment defined Integrated Assessment as "...an adaptive and participatory process that includes a pluralistic set of modeling and assessment tools and perspectives (horizontal integration) to link all stakeholders (including users, scientists, and policymakers - vertical integration)..." (Costanza and Tognetti In prep).

[5] Nordhaus was the economist present at President Clinton's televised "town meeting" on global climate change in late 1997.

Criticisms of the use of cost-benefit analysis to address environmental impacts with wide distribution in space and time have been numerous and varied.[6] The sensitivity of the conclusions of cost-benefit analysis to uncertainty about future costs and benefits, and to the value-laden choice of a discount rate, is readily admitted even by its advocates; a good discussion of the ethical issues surrounding the adoption of a discount rate can be found in Chapter 4 of the 1995 report of IPCC Working Group III (Bruce *et al.* 1996). Criticism of the aggregation of individuals and their "utility" is also not uncommon; when potential losers and potential winners are added together to equate costs and benefits at the margin, the ethical implications of the imposition of costs become invisible.[7]

There is a variety of work on possible GHG limitation regimes which quantitatively or qualitatively addresses the equity issues we consider central. Several authors compare the surplus of emissions over allocations under *per capita* or other schemes (Bertram 1992; Grubb and Sibenius 1992), or address the historical "debt" of the industrial nations (Grübler and Fujii 1991; Smith 1991). In addition, there is substantial work on equity in greenhouse negotiations which deals primarily with ethical and political considerations without necessarily linking it to quantitative models (Shue 1993; Bhaskar 1995). In what follows, we draw heavily on this work in an effort to create a model and modeling process which can reflect these concerns.

Alternatives: values and objectives

We begin our search for alternative models and modeling processes with the assertion that a GHG limitation treaty can only be legitimate if all possible stakeholders (living humans, more or less) assent to the process by which it is reached. We argue that the processes through which possible GHG regimes are being negotiated fail to meet the democratic criteria which would give such a treaty ethical legitimacy. And because we believe that the structure of many IAMs does not lead to their ready adoption in democratic processes, we attempt to put forward our own model based on criteria that we think are essential to any modeling effort.

We identify four key features which we believe are desirable in a policy-oriented model such as climate-change IAMs. This list, which is not intended to be exhaustive, includes:

1) Flexible disaggregation: any arbitrary group of persons should be able to be represented in the model;
2) Diversity of output: the impacts of climate change processes on the groups in the model should include non-monetary factors as well as monetary factors;
3) Explicit representation of values: model parameters reflecting value assumptions should be visible and user-modifiable; and

[6] See for example d'Arge *et al.* (1982); Bromley (1989); Norgaard and Howarth (1991); Page (1997), Sagoff (1988), and of course various works of Herman Daly.
[7] For example, Griffin writes that cost-benefit analysis "...accepts, even seeks, harms to individuals as long as offsetting positive effects for other individuals can be obtained." (Griffin 1995)

4) Explicit representation of uncertainty: model parameters representing uncertain processes should be visible and user-modifiable.[8]

One important project in that shares many of our concerns about Integrated Assessment models is the TARGETS project of the Dutch RIVM group (Rotmans and de Vries 1997). TARGETS specifically addresses criteria 2, 3 and 4 above, in that it provides calculated output other than dollar-valued GNP, including life expectancy, food and water availability, temperature and sea level; and it explicitly represents value choices and uncertainty through the use of "model routes" based on the perspectives of "Cultural Theory."[9] While we consider this an important effort in this field, we have concerns about the particular implementation of this effort; for example, while TARGETS includes both "individualist" and "egalitarian" values among its model perspectives, its output is aggregated in such a way that these values cannot be used to discuss the equity impacts of alternative scenarios. Other concerns about the use of "Cultural Theory" in TARGETS and elsewhere have been addressed by Risbey *et al.* (1996) and Baer (in prep).

While we believe that democratic alternatives to current modeling and modeling processes are necessary, we are bound by the same constraints that affect many other scientists and Integrated Assessment modelers. Our current work is developed almost entirely within US and European academia, and till now has no contact with broader publics. Our use of a quantitative computer model puts our discussion in a realm from which much of the world is *de facto* excluded. The central insight of our work (that judged by most ethical premises, the rich nations must cut back emissions so that the poor nations and future generations can enjoy equal life chances) requires no math and no computer, and arguably is made less rather than more accessible through their use. In spite of this, we believe that there are valuable functions to be served by providing alternative modeling tools to the communities that might use them, and it is from here that we launch the discussion of our model.

Model Overview

In the discussion that follows, we implicitly refer to an international GHG regime in which emissions are restricted through the issuing of a fixed quantity of emissions permits, allocated between nations on some basis, which could then be freely traded. We restrict our modeling here to CO_2 emissions. For discussions of potential implementation issues, and comparison with other alternative regimes for GHG limitation, see for example [REFS]

We present two slightly different versions of our basic model. In GLEAM 1.0, the world is divided simply into Rich and Poor (High Income Nations (World Bank 1997), and all others); and, after evaluating permit allocations under different principles, aggregated

[8] Obviously, clarity in user interface and documentation are also essential in a usable model, particularly one designed to be used by stakeholders and decision makers rather than just the model developers themselves. By these criteria, our own model fails miserably at this point.
[9] "Cultural Theory" derives from the work of Mary Douglas, Michael Thompson and others; see for example Douglas (1978) or Thompson *et al.* (1990).

"Welfare" is calculated in a manner consistent with the utilitarian formulation used in most cost-benefit analyses. In GLEAM 1.1, we separate out the US and India, and lump the rest of the world as "other;" after deriving permit allocations and associated income transfers, we calculate the changes in the Human Development Index (United Nations Development Programme 1998) that would be generated in order to compare welfare implications.

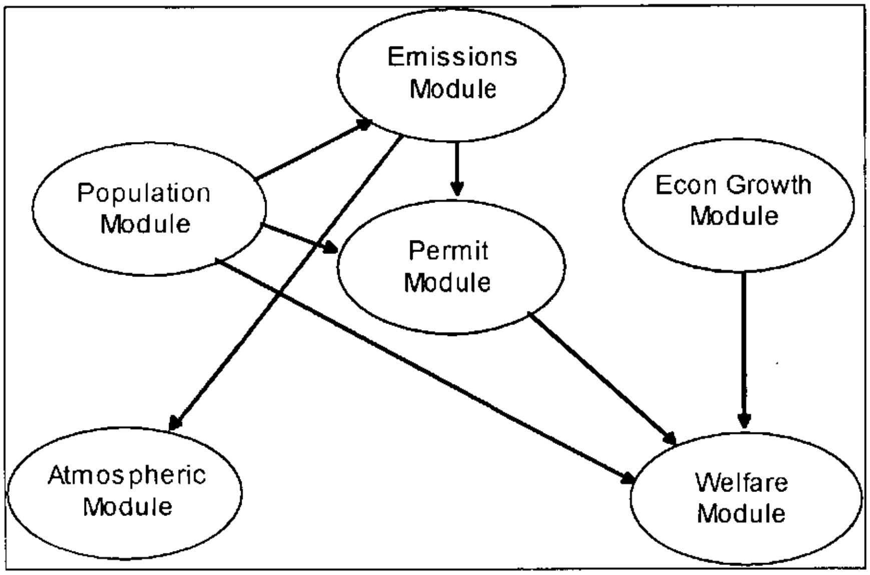

Figure 1: GLEAM Structure

Figure 1 shows the conceptual structure of the model. Clearly the model fails to reflect a myriad of known feedbacks; and although a rudimentary atmospheric module is included,[10] at this time it calculates only an atmospheric CO_2 concentration. We make no effort to derive from CO_2 concentration the possible change in global mean temperature or sea level. The only purpose is to show in a general way the implications for CO_2 concentrations of particular emissions and stabilization targets, to allow users to see the magnitude of reductions necessary to meet atmospheric concentration targets. Further development of this module is clearly essential if the model is to be expanded to include feedbacks between climate and other sectors.

Population

The population model is based on linear reductions from current population growth rates to zero growth at a specified stabilization year, which may vary by sector. This determines a unique world population total and structure at all times and a unique stabilization level. In Version 1.0 we have defined population stabilization to occur at 25 years in the rich countries and 50 years in the poor countries, which gives an optimistic stable global population of 8.1 billion persons.

[10] Our atmospheric model is based on that of Grübler and Fujii (1991), in which CO_2 concentration is calculated by a simple airborne fraction of 42% with a decay constant of 300 years.

Economic Output

Economic output based on linear reduction from current economic growth rates to a specified long-term growth rate at a specified stabilization year (Rich and Poor nations are parameterized separately). If the long-term rate is not equal to zero, economic growth continues indefinitely. In Version 1.0, stabilization occurs at 1% growth after 50 years in the rich countries and at 2% growth after 100 years in the poor countries; in version 1.1, stabilization occurs at 1% growth after 50 years in the US and at 2% after 100 years in India, with growth in the "Other" sector stabilizing at 1.75% after 75 years, reflecting the mix of rich and poor nations.

Emissions

Emissions are calculated based on the convergence of all nations emissions to a specified world per-capita level by a given target year. Rich nations' emissions (including the US in version 1.1) decline linearly from their current (*per capita*) rate to this level; Poor nation emissions (e.g., India) rise at their initial growth rate until halfway to the target year, then decline to this level. Emissions rates are in tons C *per capita*. Changes in the *per capita* rates, multiplied by population, gives total emissions by sector. Figure 2 below shows this convergence for our baseline run in version 1.0.

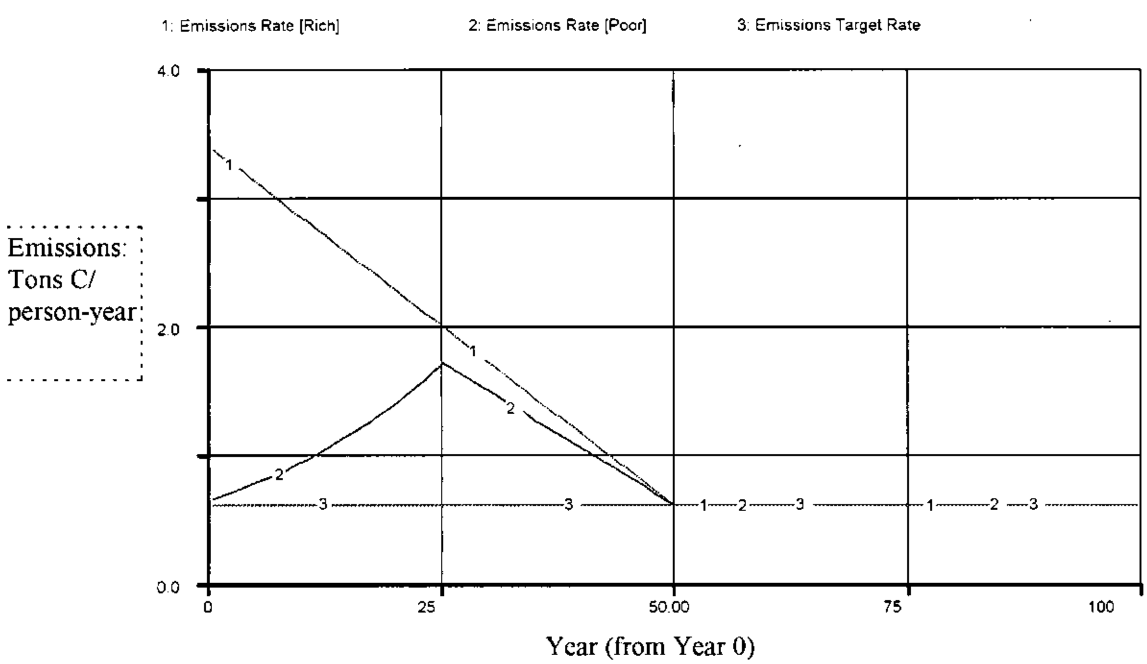

Figure 2: Convergence of Rich nation and Poor nation emissions to global average.

Permits

Emissions permits are allocated such that the total permits in a given year are equal to the sum of all nations' current emissions. Therefore the total number of permits each year is a function of the stabilization target year, the stabilization *per capita* target rate, the initial emissions rates and emissions growth rates of the various sectors.

The property rights assignment is defined with a parameter such that if Prop_Rts_Alloc = 0, permits are allocated in exact proportion to population, and if Prop_Rts_Alloc = 1, permits are allocated in exact proportion to initial emissions (grandfathering). Intermediate values allow a combination of these bases for permit allocations, which has been suggested by various authors (see for example Grubb and Sibenius 1992) as a promising basis for a GHG reduction treaty.[11]

Based on the calculated emissions rates and permit allocation, an "Emissions Surplus" is calculated for each sector. Based on a Permit Cost parameter, a figure for the monetary value of Permit Transfers is calculated. For our model runs, we have used $100 as the Permit Cost. Obviously for any fixed Permit Cost, the monetary value of transfers scales linearly.

Welfare

As suggested before, one of the innovations in this model is in the welfare module, in which the impact of income transfers from permit trading can be evaluated under different ethical premises. In version 1.0, a measure of aggregate welfare is calculated using *per capita* GDP, Permit Revenue *per capita*, and a Welfare function based on their sum. In this version, the function used is $W_i=Log(Y_i)$ where W is *per capita* welfare of sector *i* and Y_i is *per capita* income of sector *i*.[12] This formula, sometimes known as a Bernoulli or Bernoulli/Nash welfare function, takes account of the theoretical assumption of a declining marginal utility of income (or consumption) and is equivalent to that used in the objective function of Nordhaus' DICE model[13]. The aggregate measure Welfare is then equal to the population of each sector times the *per capita* welfare.

In the alternative implementation of the welfare function in version 1.1, we simply calculate the Human Development Index for the selected nations/regions. Our initial run includes the US and India as examples of nations with very different initial conditions, and an undifferentiated "Other" for which only basic information is included.[14] We calculate the adjusted Income index for each country, applying the standard HDI formula for income discounting to the income calculated by adding permit transfers to *per capita* income, and then add it to an exogenously growing "Non-income HDI components" index.

The common parameters used in both versions, as well as the parameters unique to both models, are shown in Table 1 below.

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[11] Note that in our model, permit allocations are based on current-year rather than base-year population. There is much debate in the over the implications of linking permit allocations to changing populations; there is some reason to be concerned about the incentives that this might create for increased population growth literature (see for example Grubb and Sibenius (1992), but see also Bhaskar (1995). For the purposes of this model, we will assume that the linear reduction to stable population size represents a best-case scenario and that the incentive issue can be ignored.

[12] Nordhaus' DICE in fact uses W=Log(C) where C is consumption rather than income, but the reasoning and results are similar.

[13] For further discussion see Tol *et al.* (1996) or Boadway and Bruce (1984).

[14] Because in this case "other" includes both rich and poor nations, no meaningful generalizations can be drawn and no output is provided in this paper.

PARAMETER	UNITS	GLEAM 1.0		GLEAM 1.1		
		Rich	Poor	US	India	Other
Population						
Initial Population	millions	902	4771	274	976	4680
Initial Population Growth Rate	percent/year	0.7	1.6	0.8	1.6	1.4
Population Stabilization Target	years	25	50	50	50	50
Economic Output						
Initial GDP	Billion $	22487	5200			
Initial GDP ($PPP Equivalent)	Billion $			7207	1319	26995
Initial_GDP	Billions $					
Initial GDP Growth Rate	percent/year	2.0	4.0	2.5	5.2	2.0
GDP Stabilization Rate	percent/year	1.0	2.0	1.0	2.0	1.75
Growth Stabilization Target	years	50	100	50	100	75
Initial HDI	unitless			0.943	0.451	N/A
Non-Income HDI Growth Rate	percent/year			0.1	0.5	N/A
Emissions						
Initial Emissions Rate	tons C/person-year	3.37	0.64	5.6	0.3	1.0
Emissions Stabilization Target	years	50	50	50	50	50
Emissions Target Rate	tons C/person-year	0.6	0.6	0.6	0.6	0.6

Table 1. Model Baseline Parameters. *Sources: World Resources Institute (1998); United Nations Development Programme (1998).*

Results

Baseline: Population, Economic Output, and Emissions and Climate response

With the choice of parameters for Version 1.0 given in Table 1 above, the model produces the following output for the population, economy, and emissions and climate sectors:

- Population stabilizes in 50 years at 8.1 billion persons.
- The Rich nations have total GDP of $78 Trillion/year after 100 years and *per capita* GDP of $80 thousand; the Poor nations have total GDP of $104 trillion/year and *per capita* GDP of $15 thousand.
- Emissions per year peak just under 13 Gtons C in 25 years and stabilize at 4.9 Gtons C in 50 years. Atmospheric CO2 levels reach 450 ppm in 100 years but are still climbing.

Emissions surplus, permit trades, income and welfare effects

In order to evaluate the response of the variables of primary interest (Emissions Surplus, Permit Transfers, and Welfare), we ran the model with Permit Allocation parameters of 1, 0 and 0.5, representing *per capita* emissions rights, grandfathered emissions rights, and a 50/50 mix. The results for the first 50 years are shown in the tables below.

Year	Rich Nations Emissions Surplus (Tons C x 10^6)		
	Per capita	Grandfathered	Mixed
0	2,685.38	0	1,342.69
10	2,147.67	-453.52	847.08
20	1,342.49	-1,048.77	146.86
30	683.87	-1,732.90	-524.51
40	369.25	-2,428.25	-1,029.50
50	51.43	-3,123.61	-1,536.09

Table 2. Rich nations surplus of emissions over permits (Tons C x 10^6)

Year	Pre-trade *Per capita* GDP	Net Income After Trading			Ratio of net income to pre-trade income		
		Per capita	Grandfathered	Mixed	*Per capita*	Grandfathered	Mixed
0	24.93	24.63	24.93	24.78	0.988	1.000	0.994
10	28.45	28.22	28.49	28.36	0.992	1.001	0.997
20	32.73	32.59	32.83	32.71	0.996	1.003	0.999
30	37.86	37.79	38.04	37.91	0.998	1.005	1.001
40	43.12	43.09	43.37	43.23	0.999	1.006	1.003
50	48.16	48.15	48.47	48.31	1.000	1.006	1.003

Table 3: Rich Country Income Effects

Year	Pre-trade *Per capita* GDP	Net Income After Trading			Ratio of net income to pre-trade income		
		Per capita	Grandfathered	Mixed	*Per capita*	Grandfathered	Mixed
0	1.09	1.15	1.09	1.12	1.055	1.000	1.028
10	1.38	1.42	1.38	1.4	1.029	1.000	1.014
20	1.78	1.80	1.76	1.78	1.011	0.989	1.000
30	2.32	2.33	2.29	2.31	1.004	0.987	0.996
40	3.05	3.06	3.02	3.04	1.003	0.990	0.997
50	4.08	4.08	4.03	4.05	1.000	0.988	0.993

Table 4: Poor country Income Effects

Year	Aggregate Welfare			Ratio of Case X/Y		
	Per capita	Grandfathered	Mixed	PC/Gr	PC/Mix	Gr/MIx
0	3,541.09	3,311.70	3,427.92	1.07	1.03	0.97
10	5,135.54	4,958.84	5,047.98	1.04	1.02	0.98
20	7,059.69	6,932.81	6,996.63	1.02	1.01	0.99
30	9,241.49	9,143.19	9,192.55	1.01	1.01	0.99
40	11,581.50	11,495.92	11,538.87	1.01	1.00	1.00
50	13,886.41	13,814.66	13,850.64	1.01	1.00	1.00

Table 5: Welfare Effects

As could be expected, the distribution of income between Rich and Poor nations varies directly with the number of permits the Rich nations are required to buy, which in turn depends on the permit allocation. With *per capita* allocation, Rich nations must buy permits for 2.6 x10^9 Tons C in the first year[15], declining to zero over the 50 year period during which emissions are defined to converge. In the grandfathered case, the Poor nations must begin buying permits after the first year as their emissions rise relative to the base year. In the case of a 50-50 mix of per-capita and grandfathered rights, the Rich countries must buy over 1.3 x10^9 Tons C worth of permits in the first year, but after year 20 or so the Poor countries must start buying permits from the Rich countries.

Next I compared the net income after trading of Rich and Poor nations to the grandfathered permit allocation case, in both $/person and percentage terms. Due to the disparity in income and population between sectors, the absolute amounts per person are larger in the rich countries (~$300/person in year 1 for the Rich countries vs. ~$60/year person for the Poor countries under *per capita* allocation), but the percentage impacts are much larger in the Poor countries (5.5% increase in income in year 1 for the Poor countries vs. 1.2% decrease in the Rich countries). This suggests that the burden on the rich countries is small and the benefit to the poor countries is large of the transfers associated with *per capita* emissions rights, particularly in comparison to the full grandfathering of emissions rights in which transfers from Poor to Rich are required if the Poor nations are to increase emissions to the target world average.

To quantify the effect of the declining marginal utility of income, we used the aggregated Welfare measure as described above. The results are given in table 4 above. Again, unsurprisingly given the parameters, *per capita* allocation produces the largest welfare increase, as much as 7% more than grandfathered allocation in year 1. The significance of the result is that based on the same function for declining marginal utility of income that is used to justify the setting of an "optimal" emissions rate in Nordhaus' model, *per capita* emissions rights can be shown to produce the greatest total welfare.

Results of Version 1.1

Because the only significant differences between the two versions are the choice of countries/regions and the calculation of the welfare index, we present only a few tables for the second version. In tables X and Y we present the impact of *per capita*, grandfathered, and mixed emissions allocations on the income component of HDI and the full HDI for India and for the US. These tables show that permit trading based on *per capita* allocation compared to grandfathered or mixed rights gives a significant increase in the income component of the HDI for India, and a small increase in the overall HDI, while having a negligible impact on the HDI for the US or its income component. While we chose India because it is one of the largest and most significant of the developing countries in terms of possible impacts on global climate from its development path, it has a significantly higher *per*

[15] At our base case Permit Cost of $100/Ton C, this translates directly to $260 billion in Year 1 under per capita allocation. This is clearly a large amount of money, but on the same order of magnitude as official development assistance flows ($40-50 billion/year around 1990), annual developing country debt service payments (about $160 billion/year in 1990), or Rich nation arms spending (about $500 billion/year in 1990) (various sources in Bertram (1992)).

capita income in PPP$ than many African nations, in which HDI benefits from trading could be much larger. Moreover, India (like most developing countries) has a much lower GDP based on exchange rates ($349 in 1995) than as measured by PPP – ($1420 in 1995) (World Resources Institute 1998). This implies that the income from permit trading could have a much greater impact on India's development alternatives based on its effect on the balance of payments than it would have on the short-term consumption options of its population.

	HDI Income Component and Full HDI (India)					
	Per capita		Grandfathered		Mixed	
Year	Income Index	HDI	Income Index	HDI	Income Index	HDI
0	0.214	0.451	0.201	0.447	0.208	0.449
10	0.272	0.490	0.258	0.485	0.265	0.487
20	0.340	0.533	0.326	0.528	0.333	0.530
30	0.421	0.581	0.409	0.577	0.415	0.579
40	0.515	0.635	0.508	0.633	0.511	0.634
50	0.619	0.693	0.615	0.692	0.617	0.693

Table 6: India HDI Effects

	HDI Income Component and Full HDI (US)					
	Per capita		Grandfathered		Mixed	
Year	Income Index	HDI	Income Index	HDI	Income Index	HDI
0	0.991	0.942	0.991	0.943	0.991	0.943
10	0.990	0.948	0.990	0.948	0.990	0.948
20	0.992	0.955	0.992	0.955	0.992	0.955
30	0.994	0.962	0.994	0.962	0.994	0.962
40	0.994	0.968	0.994	0.969	0.994	0.968
50	0.993	0.975	0.993	0.975	0.993	0.975

Table 7: US HDI Effects

Conclusions and Future Directions

GLEAM currently allows calculation of the quantity of permit trades associated with given levels of emissions, economic growth, population, and the size of transfers of income associated with permit trades given the permit price. It does not currently include any feedbacks between emissions and economic or population growth, any accounting for historical emissions, or any endogenous (or exogenously time-dependent) changes in permit prices. All of these developments, which we are considering for future versions, would make the model substantially more useful for evaluation of anything beyond the first few years of the experiment, and would make it comparable in more dimensions to IAMs such as DICE and others.

It is our belief that we will see an increasing use of simulation models in negotiations over environmental and other policy conflicts, including global climate change policy. While many experts and laypersons believe that international treaties evolve primarily out of power politics, and thus that arguments over ethical and moral principles are irrelevant in negotiations, a strong case can be made that they are not (see for example Bhaskar 1995). We envision a model such as GLEAM being used as a simulation exercise in the form of a game among both decision-makers and laypersons, in such a way as to bring forward the relevant issues and potentially shape the final agreement .[16]

In one possible version, the game would be in the negotiation of the terms of the agreement to be implemented, by players operating under a Rawlsian "veil of ignorance" (Rawls 1971) as to their geographic and generational position; subsequent to agreement, the negotiators would be randomly assigned to a position in the current and future world. If Rawls' hypothesis about risk aversion is correct, running through a sufficiently large number of iterations should lead to a convergence of opinions on a properly cautious approach and a just distribution of the costs of restraining emissions.

Participating in a simulation exercise such as mentioned above is one way in which people can be brought to see the world from a perspective other than their own. And we believe that people can and will change their beliefs and their practices (and some but not all of their values) as it becomes increasingly clear that, in the words of The Police, "we all sink or we all float, 'cause we're all in the same big boat."

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[16] One attempt to bring relatively sophisticated models of climate change and related issues to a lay public is the ULYSSES project carried out by the Joint Research Center (Pereira *et al.* 1998). Although this project was restricted to European nations, it is an important step in the right direction, and their experiences should be reviewed and discussed by all those interested in the development of more participatory relationships between modelers and other scientists and the general public.

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