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International climate treaties: The case for pessimism

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I. Introduction

What hope should we have that a binding, international agreement will be negotiated and lead to reductions in GHG emissions sufficient to avert dangerous levels of global warming? In this article we argue the case for pessimism on theoretical and historical grounds, arguments that we believe take on added importance in light of what happened at the Fifteenth Conference of the Parties to the UN Framework Convention on Climate Change in Copenhagen in December 2009.

Although the influence of increased greenhouse gas concentrations on the earth's climate was the subject of sporadic scientific interest in the nineteenth century, it was not until the 1950 s that it became embedded in systematic research programs. It made it onto the international political agenda some thirty years later, and now (twenty years farther along) it is at the centre of much international discussion.

Through game-theoretic models, economists and political scientists have derived what amounts to a checklist of relevant, national incentives that need to be in place for a global climate treaty to work. We present here a simple overview of those incentives and their importance, and show why it will be particularly challenging to put them in place for a global climate treaty. The very existence of a global climate regime may seem to contradict our claim that effective binding international climate agreements are unlikely. However, measured against the magnitude of the challenge posed by anthropogenic climate change, our review of the Kyoto Protocol and its impact suggests that it has so far been a largely ineffective treaty with no or little impact on global emissions. Hence, the history of the Kyoto Protocol confirms the case for pessimism more than it does the contrary position.

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In making this argument we do not wish to be interpreted as supporters of apathy or nihilism. If we are to hope that the international society will manage to avoid undesirable climate change, however, we need to know both what challenges we face and the extent to which our current efforts and attempts to solve the issue are sufficient and moving us in the right direction. There seemed to be basis for modest optimism in the wake of the new climate policy of the US administration, but this more progressive US policy did not help much in Copenhagen, and China has now emerged as the main laggard. Considering the modest results on the UN track, we argue that an interaction between the UN track and soft-law, and less inclusive approaches such as the Asia-Pacific Partnership on Clean Energy and Development (APP) and the Major Economies Forum on Energy and Climate (MEF) may be needed in the short run. In the long run, however, there is little reason for optimism due to expected strong economic and population growth in the South—unless, of course, some unexpected "technological fixes" can be developed.

II. The Climate Regime: A Brief Overview

However beautiful the strategy, you should occasionally look at the results (a saying commonly attributed to Sir Winston Churchill).

The issue of climate change and its implications for society began to get attention outside of the scientific arena in the 1970 s. By 1989, the Intergovernmental Panel on Climate Change had been established, and the UN General Assembly decided a climate convention should be negotiated under the auspices of the UN.

As is well known, the UNFCCC was adopted at the 1992 Rio summit and came into force in 1994. Industrialized states were asked to stabilize emissions at 1990 levels by the year 2000. The Berlin Mandate adopted at COP 1 in 1995 acknowledged the need to strengthen Annex I commitments beyond 2000. This was taken a step farther with the adoption of the Geneva Declaration at COP 2, calling for legally binding quantified emission reductions within specified time frames. At COP 3 in Kyoto in 1997, the Protocol was adopted. A flexible approach towards implementation was sought via three market-based mechanisms: joint implementation, permit trading, and the Clean Development Mechanism. The Protocol required ratification by countries representing 55 per cent of the CO_2 emissions from Annex I countries in 1990, which was fulfilled when Russia ratified in November 2004. The Protocol came into force in February 2005, more than seven years after it had been negotiated.

The national quotas of Annex I countries under the Protocol are set about five per cent below their 1990 emissions, but differentiation is considerable and without any explicit or obvious rationale. Reductions affecting a basket of six greenhouse gases are to be attained within a multi-year target, with compliance based on each country's emissions over a five-year period from 2008 to 2012. The Protocol also allows Annex I parties to take into account changes in land use: offsetting emissions by reducing their rate of land clearing or increasing forest coverage (LULUCF). These provisions, which we will comment on in more detail later, were introduced to make implementation less costly.

At COP 13 in Bali in 2007, agreement was reached on the Bali Roadmap. Two working groups were established: the Ad Hoc Working Group on the Kyoto Protocol, involving the parties to the Protocol, and the Ad Hoc Working Group on Long-Term Co-operative Action, involving all UNFCCC parties (including US). Negotiations were to be conducted on the four building blocks of mitigation, adaptation, finance, and technology. The goal was to complete negotiations of a new climate treaty at COP 15 in Copenhagen. Towards that end, the process of negotiations was intensified. Up until Bali there had been two negotiation sessions per year. In 2008 four sessions were arranged, while there were five sessions in 2009, prior to Copenhagen. As we now know, the intensified process produced few results. Just before COP 15 it was clear that the best one could hope for was a soft political agreement with no legal teeth. For much of the duration of the conference it seemed COP 15 would be a complete fiasco, but backroom efforts by a small group of states, the US and four "emerging powers" (Brazil, China, India, and South Africa) were able to hammer out a deal, the Copenhagen Accord.

III. The Barriers to an Effective Climate Agreement

How human emissions affect the climate, at what time-scale this happens, and at what level the atmospheric inflow of human GHG emissions is balanced by natural outflows resulting in stable atmospheric GHG concentrations, are all questions for natural science rather than social science. In this sense, the ambition or goal of a climate treaty is based on or influenced by our scientific knowledge of natural processes. If the natural scientists are right in their predictions, destructive climate change can only be avoided by dramatically cutting global GHG emissions from current levels. The question of how such ambitions may be realized is one for the social sciences. An effective climate treaty will need to induce a large number of countries to implement stringent measures so as to reduce their emission levels, and this requires politicians, voters, and consumers to make new and unusual choices.

Game theory is a methodological approach frequently used by economists and political scientists to analyse proposed treaty mechanisms and their implications. A game in this context is any choice situation with a strategic aspect, that is, a situation where a choosing agent needs to take into account that the actual outcome reached will also depend on the choices of other agents, and that these will be influenced by speculation upon the first agent's actions, and so on. Game theory formulates the strategic situation mathematically, and allows the researcher to explore the implications of the incentives and structure that define the situation, usually under the assumption of rational, well-informed agents basing their decisions on sophisticated computations.

Game-theoretic analyses have helped clarify what it requires for a treaty to be in alignment with the participants' national self-interest at *all* the relevant choice steps in the treaty process. It is not enough for there to be a good case for international coordinated action. Each country must also find it in its national interest to participate in the treaty. It must also find it in its national interest to agree to a binding and costly obligation, to actually fulfill that obligation in practice, and to help punish others who fail to do so.

While game theory has been useful and has provided several important insights, our aim here is not to present a primer or review of the literature.[2] Rather, our aim is to use results and perspectives from game theory as a way of framing and clarifying what we feel to be the main barriers in the way of a working, effective, and global climate treaty.

IV. Complexity, Lags, and Uncertainty—The Problem of Wishful Thinking and Procrastination

In cataloguing the challenges for an international climate treaty, we start with three issues that are immutable aspects of the climate change problem itself, as opposed to "collective-action" problems. The stock/flow dynamics of the climate system are difficult to grasp intuitively. Even if we do grasp them, however, the effects of current emissions lie so far into the future that they motivate us weakly. And even if we did not disregard/discount future effects as much as we do, uncertainty about future developments in technology and science make it all too easy to procrastinate while we wait for progress in those fields to make emission cuts less costly or necessary. These are factors that can promote procrastination, wishful thinking, and over-optimism even in the absence of the collective-action issues we turn to later.

The dynamics of the climate system are driven by a stock/flow relationship: emission flows increase atmospheric stocks of GHG, which in turn influence the global climate. Unfortunately, the inability to understand stock/flow relationships seems widespread and persistent—84 per cent of student engineers, economists, and other university students, given the task of charting the emission and removal paths they think would be consistent with a certain stock build-up, draw trajectories violating mass-balance requirements. Stock build-up equals the amount added minus the amount taken out, but according to the charts drawn up, stocks were thought to reduce even when the net amount added was large and positive.[3]

The common, intuitive, model seems to be that the current climate is determined, with a lag, by the *current flow* of human GHG emissions.

The flaw may be easier to see if we take the case of a bathtub, that is, a simpler and more familiar stock/flow system. The intuitive model alluded to above is equivalent to the belief that the water level in a bathtub would start to fall if we were to slightly reduce the flow from the tap, *even if* the inflow from the tap remained greater than the outflow from the drain. In reality, of course, the water will continue rising as long as the net inflow is positive; but apparently this is less obvious

[2] See, for example, Scott Barrett, *The Theory of International Environmental Agreements*, *in* Handbook of Environmental Economics 1457 (Karl-Göran Mäler and Jeffrey R. Vincent, eds., 2005); Charles D. Kolstad and Michael Toman, *The Economics of Climate Policy*, *in* Handbook of Environmental Economics (Karl-Göran Mäler and Jeffrey R. Vincent, eds., 2005); Ulrich J. Wagner, *The Design of Stable International Agreements: Economic Theory and Political Economy*, 15 Journal of Economic Surveys 377 (2001).

[3] John Sterman and Linda Sweeney, *Understanding Public Complacency about Climate Change: Adults' Mental Models of Climate Change Violate Conservation of Matter*, 80 Climatic Change 213, at 225 (2007).

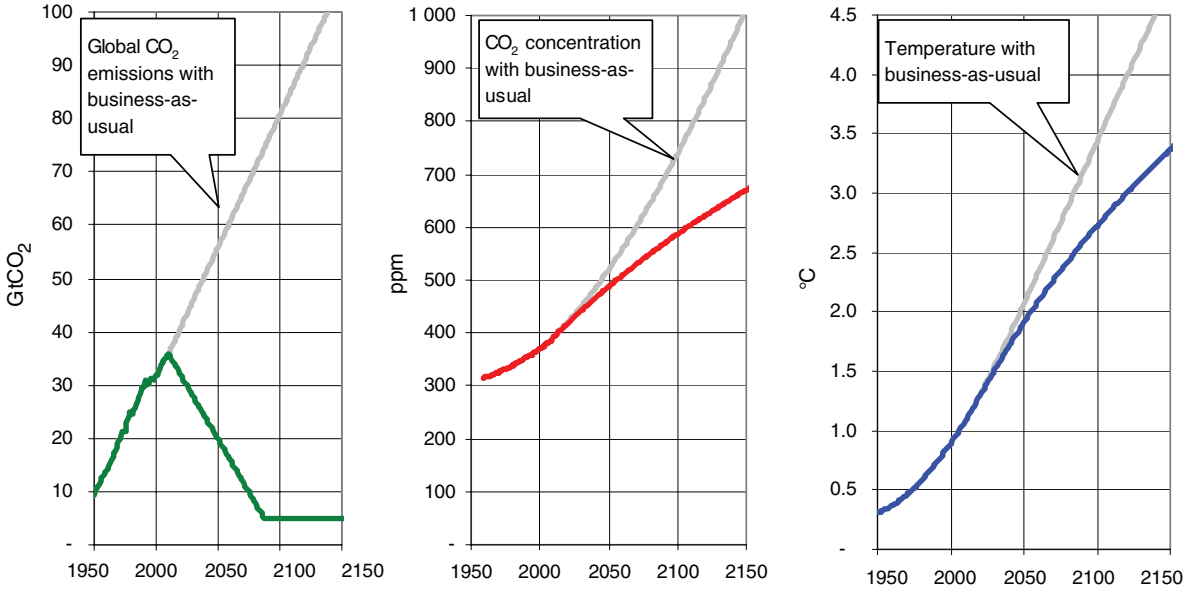

Figure 1. The diagram on the left shows a linearly increasing global emissions business-as-usual scenario (grey curve) and a scenario that stabilizes global emissions at current levels (colored curve). Under the latter scenario, the CO_2 concentration in the atmosphere would continue to grow (middle diagram). So would the global temperature (right diagram). (Source: see footnote 5.)

when thinking about the atmosphere.[4] Figure 1 uses a simplified model of the climate system to show how the atmospheric CO_2 concentration (and resulting global mean temperature) would continue to rise even if emissions stabilized at today's level.[5]

To actually stabilize the temperature would require even more drastic cuts. Figure 2 illustrates one stabilization case, which requires global CO_2 emissions to fall to ten per cent of today's level by 2100. Emission reductions of this scale are a significant challenge, especially against the backdrop of an expected 600-1,200 per cent economic expansion over the same period,[6] in combination with the substantial population growth[7] displayed in Figures 3 and 4.

[4] The IPCC executive summary notes that current human emissions are at twice the "net removal rate" of the system. The net removal rate is expected to fall, for instance due to a reduced absorptive capacity of the oceans. Sterman and Sweeney, supra note 3, at 225.

[5] With regard to the dynamic relationship between global CO_2 emissions, the CO_2 concentration in the atmosphere, and global temperature increase, all numerical examples in this paper are based on the simulation of a numerical model as described in Niklas Höhne and Kornelis Blok, *Calculating Historical Contributions to Climate Change—Discussing the 'Brazilian Proposal'*, 71 Climatic Change 141 (2005). With regard to the business-as-usual scenario, see footnote 16.

[6] Primarily due to growth catch-up from developing and emerging economies; see Nebojsa Nakicenovic et al., Special Report on Emissions Scenarios: A Special Report of the Working Group III of the Intergovernmental Panel on Climate Change (2000).

[7] The human population may approach 10 billion by 2050; see United Nations, World Population Prospects: 2006 Revision, vol. 1: Comprehensive Tables (2008).

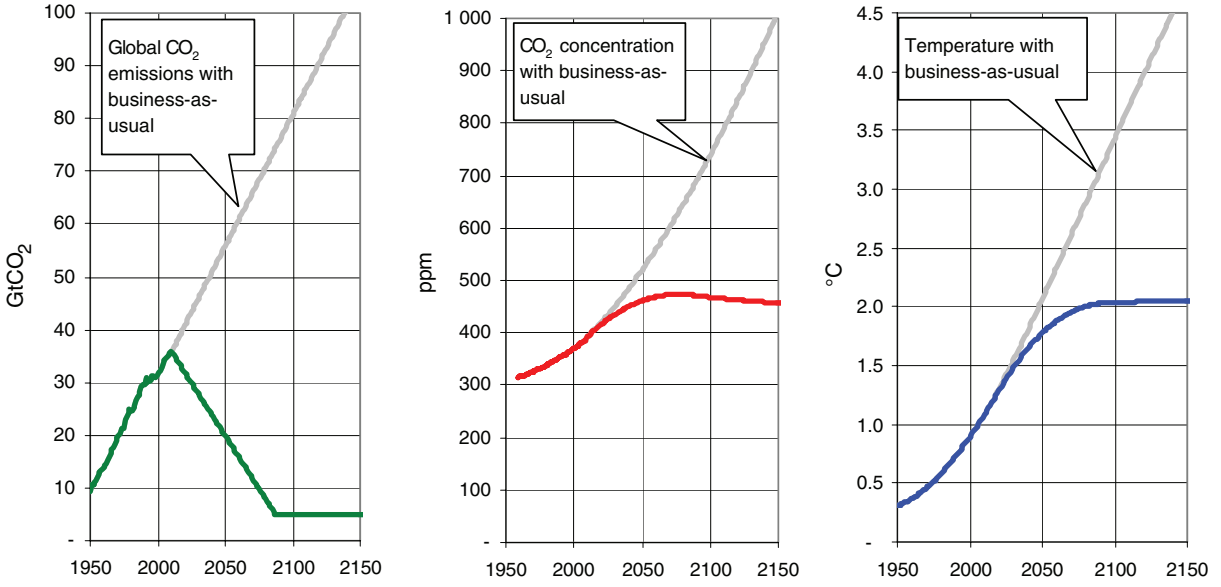

Figure 2. The left diagram shows a business-as-usual scenario with linearly increasing global emissions (grey curve) and a very ambitious emission-reduction scenario (colored curve). This would stabilize CO_2 concentrations towards the middle of the second half of the 21st century (middle diagram). The temperature is stabilized towards the end of the century (right diagram). (Source: see footnote 5.)

Figure 2 also illustrates our second point, that the effect of current emissions on the climate is spread out over a long period. Even though emission cuts in Figure 2 are made immediately, the global temperature would stabilize only around the period 2080-2090. This means that where negative consequences of climate change due to *past* emissions are experienced, such consequences could not be addressed by slashing current emissions. The benefits of today's emission cuts would not be fully realized until decades into the future, although unless the cuts were sufficient to bring down total atmospheric stocks of greenhouse gases, those benefits would only be relative to an even worse business-as-usual climate that we had managed to avoid. This makes it tempting (especially for politicians focused on a four-year election cycle) to focus on adaptation measures that alleviate and reduce actual, observed problems, rather than on abatement efforts that will reduce additional problems in the distant future.

Third, there is the issue of fundamental uncertainty of the future, which gives rise to what we might call the "money-might-conceivably-be-saved-by-waiting" motive for procrastination. This refers both to scientific, technological, and "political" progress. Remaining scientific doubt is still seen by some as evidence that the problem may turn out to be less serious than we think it is today; they range from those who think that the problem may be less severe, to "deniers", like Sarah Palin, who see climate science as a global conspiracy driven by scientists with ominous

political agendas.[8] Technologically, there is the hope that future generations will develop more and possibly far cheaper and better options for reducing emissions, removing carbon dioxide directly from the atmosphere (air capture), geoengineering a better climate directly, adapting to a changed climate, etc. Politically, there is the hope that future climate treaties will be based on "efficiency-promoting" market mechanisms that allow rich countries to avoid painful and costly domestic measures by (in effect) paying poorer countries to reduce their already low emissions or plant more forests.

A real-world illustration of such a "procrastination incentive" may be the Carbon Capture and Storage technology meant to remove GHG emissions from coal and gas power plants. A common conviction among politicians that CCS will become widespread and affordable in a couple of decades can make it easier to postpone action, despite the lack of a full-scale demonstration project and large cost overruns at existing pilot plants.

All in all, these factors might explain the weak targets discussed politically. The Kyoto Protocol, the only existing international abatement treaty, would have a marginal effect on temperature even in the (unlikely) case of full compliance by all Annex I countries.[9] And even the political visions put forth by various country leaders fall dramatically short of what is required: a recent conference paper tried to quantify the environmental impact of having all major political emission-abatement goals (from the US and the EU to India and Brazil) actually realized. Feeding this information into a climate model indicates that it would result in an increase in global mean temperature of four degrees Celsius by 2100 and an atmospheric concentration of GHG above 700 ppm[10]—to be contrasted with the "safe" level generally thought to be in the 350-450 ppm range.

V. Attracting Signatories—The Tragedy of the Commons

We turn now to the collective-action issues analysed by game theorists. One set of issues concerns the incentives for countries to free-ride on the abatement efforts of others, by not joining a treaty, not being willing to abate, or only being willing to abate if others pay for the costs incurred. The incentives such conduct are quite strong, and we argue that self-interested incentives of this kind lie behind many of the debates phrased in ethical terms, such as "fairness" and "justice".

[8] Here is Sarah Palin on the politicization of the Copenhagen climate conference, Washington Post, 9 December 2009: "'Climate-gate', as the e-mails and other documents from the Climate Research Unit at the University of East Anglia have become known, exposes a highly politicized scientific circle—the same circle whose work underlies efforts at the Copenhagen climate change conference. The agenda-driven policies being pushed in Copenhagen won't change the weather, but they would change our economy for the worse."

[9] Jon Hovi, Tora Skodvin, and Steinar Andresen, *The Persistence of the Kyoto Protocol: Why Other Annex I Countries Move on Without the United States*, 3 Global Environmental Politics 1, at 4 (2003).

[10] Elisabeth R. Sawin et al., *Current Emissions Reductions Proposals in the Lead-up to COP-15 are Likely to be Insufficient to Stabilize Atmospheric CO2 Levels: Using C-Roads—A Simple Computer Simulation of Climate Change—to Support Long-term Climate Policy Development*, paper presented at the "Climate Change—Global Risks, Challenges, and Decisions" conference, University of Copenhagen, Denmark (March 2009) <www.climateinteractive.org/simulations/C-ROADS/simulation-media/publications>.

In the terminology of economics, GHG abatement is a public good subject to the so-called "tragedy of freedom in the commons". Based on Lloyd (1833), Hardin (1968)[11] illustrates the case by picturing a pasture open to all, with many herdsmen, each with their own little herd of animals. Each herdsman thinks about his own payoff from adding another animal to his herd—that is, the money he gets from selling it later. Adding another animal, however, also has a cost, in that, after a certain threshold, it adds to overgrazing. Most of that cost, however, is borne by other herdsmen. As long as this is disregarded, each herdsman finds it in his private interest to add more animals to his herd (pushing the cost onto the others), and the result is ruin for all.

In a similar way, each nation finds it in its private interest to emit more GHGs, as long as it accords more weight to its own benefit from emitting the excess than to the harm it causes the "rest of the world". The phenomenon seems to hold in reality even for large nations that are major emitters. To see this, consider three numerical-model simulations that display the reduced global warming in 2025, 2050, and 2100, when the world's three largest countries undertake large emission reductions unilaterally.

First, Table 1 shows the case where China, *on a unilateral basis*, follows a path of emission reductions of 20, 60, 95, and 100 per cent from business as usual in 2025, 2050, 2100, and 2200, respectively. Following such a path would imply implementation of very tough, costly emission-reduction policies in China. Emission reductions of that scale would necessarily imply very high taxes on fossil-fuel consumption (or other corresponding carbon-pricing policies) affecting all Chinese households and businesses. Nevertheless, the result would be a relatively modest slowdown of global warming: a lowering of global temperature of 0.01, 0.07, 0.23, and 0.34 degrees Celsius in 2025, 2050, 2100, and 2200, respectively.

Table 1

The effect on global mean temperatures of a single country's emission reductions. The cases of China, India, and US. The table shows the result of three different model simulations, where each simulation measures the effect on global mean temperatures of a single country reducing emissions unilaterally—with all others emitting at business as usual. The countries are China, India, and the US. The model is the same as the one described in footnote 5

	Emission reductions from BAU*	Reduced global mean temperature from BAU (degrees Celsius)		
		China	India	USA
2025	–20%	–0.01	–0.00	–0.01
2050	–60%	–0.07	–0.03	–0.06
2100	–95%	–0.23	–0.12	–0.17
2200	–100%	–0.34	–0.21	–0.15

* Business as usual.

[11] See Garrett Hardin, *The Tragedy of the Commons*, 162 Science 1243 (1968); William Forster Lloyd, Two Lectures on the Checks to Population (1833).

Table 1 also shows the corresponding numbers in the cases of India and the US. The picture is the same: the effect of unilateral action is small no matter how large the country. It follows that, for any country, the isolated effect of domestic action is negligible. At the same time, the abatement cost and political cost to governments would be large if substantial emission reductions were to be carried out. The temptation to ignore the problem is therefore strong: "My contribution doesn't have much impact, so why should I do something costly that won't affect the big picture?" Given this logic, it may be difficult to motivate the public in any country to accept politically raised end-user prices on fossil fuels and other abatement policies.

While the tragedy of the commons could easily be solved by a national government's intervention, the overuse of the atmosphere as a disposal site has to be solved through an international agreement, as no supranational international authority exists to enforce contracts. A large game-theoretic literature has grown up arguing that an effective international climate agreement is difficult to establish and implement: Scott Barrett and Michael Hoel[12] made early contributions to this literature, and Barrett has also made more recent contributions.[13] A counterintuitive but important result in this literature is that an agreement with broad participation is harder to reach the higher the potential benefits to cooperation. The potential benefit is higher the more our selfish actions deviate from the cooperative solution, but the more a treaty requires us to deviate from our own selfish solution the less we want to participate.

That is not to say that the literature is unable to produce more optimistic results, though these are sometimes difficult to translate into a real-world setting. As an example, a recent model by Larry Karp and Jinhua Zhao shows that the introduction of a set fine for parties not meeting their abatement targets might allow a broadly inclusive agreement to be formed even when the benefits of cooperation are large.[14] The mechanism hinges on each nation X knowing how the other treaty members will respond to X's decisions (join/exit, abate/pay fine). There is a threshold at which each nation participating knows that its exit would cause a substantial number of other participants to either exit or stop abating. As a self-interested nation, you will not be interested in abating if your abatement costs Y dollars and provides your nation with $Z < Y$ dollars of benefits. However, if your choice to abate *causes* other nations to do so as well, by altering the incentives they face, then these *repercussions* of your choice need to be taken into account by being added to your payoffs: while your own abatement still costs Y, and while your own benefit from this abatement is still $Z<Y$, you now also take into account the benefit to your nation of the increased abatement you have triggered in the nations you influenced.

Taken literally as a method to increase participation in practice, this mechanism seems non-persuasive. The impact of a nation's actions on the actions of another would likely be taken into

[12] Scott Barrett, *Self-enforcing International Environmental Agreements*, 46 Oxford Economic Papers 878 (1994); Michael Hoel, *International Environment Conventions: The Case of Uniform Reductions of Emissions*, 2 Environmental and Resource Economics 141 (1992).

[13] Scott Barrett, Environment and Statecraft: The Strategy of Environmental Treaty-Making (2003); and Barrett, supra note 2.

[14] Larry Karp and Jinhua Zhao, *A Proposal to Reform the Kyoto Protokol: The Role of Escape Clauses and Foresight*, working paper (2007) <http://are.berkeley.edu/~karp/KyotoReformFeb07.pdf>.

account in a looser way and in specific contexts (a small nation's effect on neighboring countries, or a large nation's impact as a "global leader"). The repercussions of your nation's decision on the decisions of other nations is less clear-cut and less sharply determined in a known way from objective factors. We acknowledge that this is just one example of an optimistic model. However, all game-theoretic models that increase participation require some interdependence of choice—some way of making *your choice* have an added impact by *altering the actions of others*—whether because of thresholds in effects, non-linearities, economies of scale in technology, etc. The credibility of the results hinge on the credibility and real-world importance of the interdependence assumed.

We conclude from this that the incentives to free-ride are real and significant—within treaty negotiations as well as in the deliberations on whether or not to join a treaty, and for larger as well as smaller nations.

The problem is compounded by the need to dramatically shift the emission trajectories in both developed and developing nations. OECD countries are responsible for 48 per cent of current CO_2 emissions,[15] roughly equal to the IPCC estimate of the current net removal of GHGs from the atmosphere by natural processes. Mainly due to limits on the oceans' capacity to absorb CO_2, this net removal is expected to fall, so that a long-term sustainable level of emissions is less than current OECD emissions. In other words, even a utopian scenario that involves *zero emissions* from non-OECD countries, which are home to 80 per cent of the global population, necessitates abatement in OECD countries.

If only the developed countries reduced their emissions, this would have little effect on the climate problem: the developing-country population is expected to double by the end of the century, while economic growth in a business-as-usual case is expected to more than triple the per-capita emissions. These effects interact multiplicatively, so that the overall increase in emissions from poor countries over the century is roughly seven times the current level over the century (see Figures 3–6).

The business-as-usual scenario in Figures 3–6 is based on the per-capita emissions assumed in the IPCC's A1 scenario (see the grey curves in Figure 2).[16] In this scenario, the per-capita

[15] Energy Information Administration, Office of Integrated Analysis and Forecasting, US Department of Energy, *Emissions of Greenhouse Gases in the United States 2007* (2008) <www.eia.doe.gov/oiaf/1605/ggrpt/pdf/0573(2007).pdf>.

[16] Nakicenovic et al., supra note 6. The global emissions projections in the IPCC Fourth Assessment Report are taken from IPCC's Special Report on Emissions Scenarios, the so-called SRES scenarios (Nakicenovic et al., supra note 6). The 40 SRES scenarios are grouped within four so-called families of scenarios, A1, A2, B1 and B2. In A1 and B1 the economic growth is high (especially in A1) and there is a rapid technological development that improves energy efficiency. In B1 there is, in addition, a high degree of decarbonisation of the energy supply. In A2 and B2, population growth is high and economic growth low, while the energy-efficiency improvements are small compared to A1 and B1. These characteristics are especially pronounced in A2. We have chosen to apply the per-capita emissions in the A1 scenario. The global emissions of this scenario are somewhere in the middle of the 40 SRES scenarios.

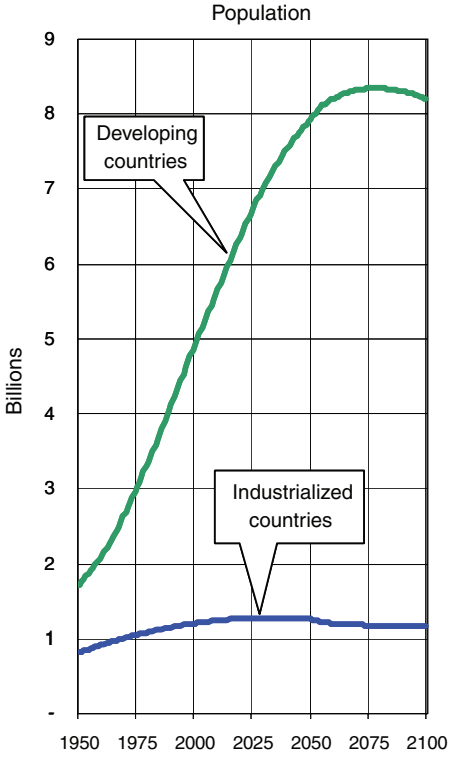

Figure 3. Actual and projected population levels in developing and industrialized countries, 1950-2100. UN population projections, medium scenario. United Nations, World Population to 2300 (2004).

CO_2 emissions are decreasing also in the developing countries during the last decades of the century. This is due to an assumed technological breakthrough giving rise to expansion of energy from biomass and other renewables. During the whole century there is assumed to take place a continuing spontaneous technological change giving rise to a steadily decreasing energy intensity of the world economy. This is also the reason why the per-capita emissions in developed countries are decreasing during most of the century. We follow the IPCC in assuming that this rapidly increasing energy efficiency will be realized even in the absence of a climate policy, although the IPCC's assumption at this point could be questioned.[17] With respect to population growth, we have applied the medium variant in the World Population Prospects,[18] instead of the older population projections used by the IPCC.

Our reference case involves total, cumulative, CO_2 emissions of more than 5,800 Gt CO_2 over this century, to be contrasted with how much we could emit without causing dangerous climate change. The question was addressed in a recent paper in *Nature*, which stated that "Limiting cumulative CO_2 emissions over 2000-50 to 1,000 Gt CO_2 yields a 25 per cent probability of

[17] See, for example, Roger Pielke, Tom Wigley, and Christopher Green, *Dangerous Assumptions*, 452 Nature 531 (2008).

[18] United Nations, supra note 7; United Nations, *World Population to 2300* (2004).

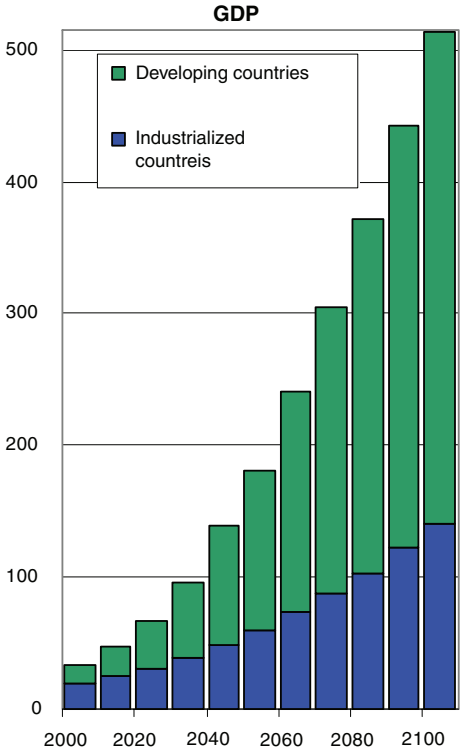

Figure 4. Projected GDP (PPP) in the IPCC's A1 scenario, trillion $US, 1990 prices. Source: N. Nakicenovic et al., Special Report on Emissions Scenarios: A special report of Working Group III of the IPCC (2000).

warming exceeding 2 °C".[19] The authors of that paper also note that "known 2000-06 CO_2 emissions were ∼234 Gt CO_2", which means that, counting from around 2010, we would have about 700 Gt CO_2 "left" to emit by 2050. Assuming that 2050-2100 emissions need to be negligible in order not to increase temperatures further, this suggests that total emissions over the century need to be reduced by more than 85 per cent compared to business as usual, and that that reduction must be achieved between now and 2050. As Figure 6 makes clear, most of the reduction necessarily must happen in emerging economies, simply because that is where most of the business-as-usual emissions are expected.

The treaty discussions of how to "split the bill" is often couched in terms of ethics and fairness, with countries supporting and promoting principles that will support a treaty beneficial to themselves. A rich, developed, country may argue that quotas should ensure that everyone gradually reduces emissions from their current level, loosely taking into account energy mix and the costs of abatement. For instance, former US president George W. Bush, as well as Australia's conservative former prime minister John Howard, stated that they would not enter treaty discussions

[19] Malte Meinshausen et al., *Greenhouse-gas Emission Targets for Limiting Global Warming to 2°C*, 458 Nature 1158 (2009).

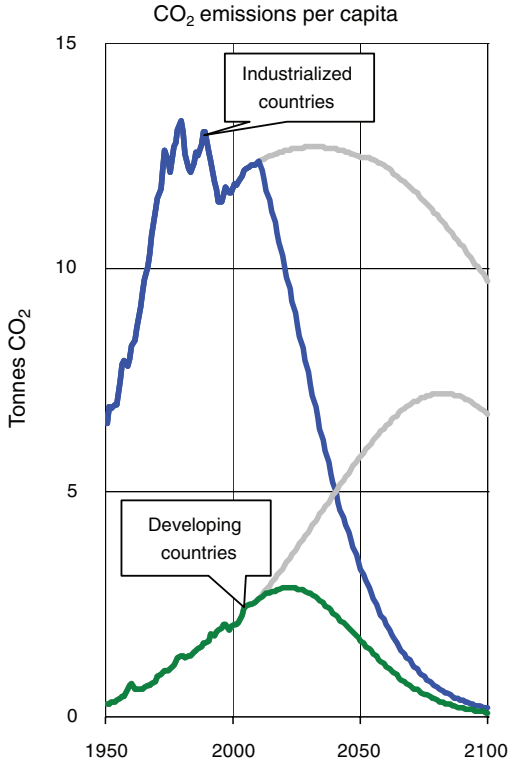

Figure 5. Global per capita CO_2 emissions in developing and industrialized countries. Grey curves represent the IPCC reference A1 scenario. Blue and green curves represent historical emissions and emissions consistent with the target to limit the increase in global temperature to a maximum of 2 °C over pre-industrial levels, in developed and developing countries, respectively.

unless key developing countries such as India and China agreed to abate their emissions.[20] At COP 15, getting China to enter a global emission-regulating framework was likewise a major focus of President Obama. Developing countries, on the other hand, argue from per-capita emissions (or cumulative historic emissions). For instance, India's prime minister Manmohan Singh stated that first-world polluters must make the first move, and that India would then ensure that their per-capita emissions would not exceed that of the western countries.[21] For an indicative figure for what is at stake here, the Stern Review has estimated the cost of avoiding dangerous climate change at one-to-four per cent of annual global GDP over the century. To the extent that current negotiations are determining how this over-the-century cost should be borne by different countries, they are (in undiscounted terms) negotiating over a sum several times the size of the current global GDP.

[20] *Bush Faces Up to Kyoto Critics*, BBC News, 11 June 2001 <http://news.bbc.co.uk/2/hi/americas/1382564.stm>. Jonathan Holmes, *John Howard Interview—Energy*, Australian Broadcasting Corporation, 2006 <www.abc.net.au/4corners/content/2006/s1738726.htm>.

[21] Krittivas Mukherjee, *India's Climate Change Roadmap to be Ready in June*, Reuters, 7 February 2008 <www.reuters.com/article/idUSSP28730620080207>.

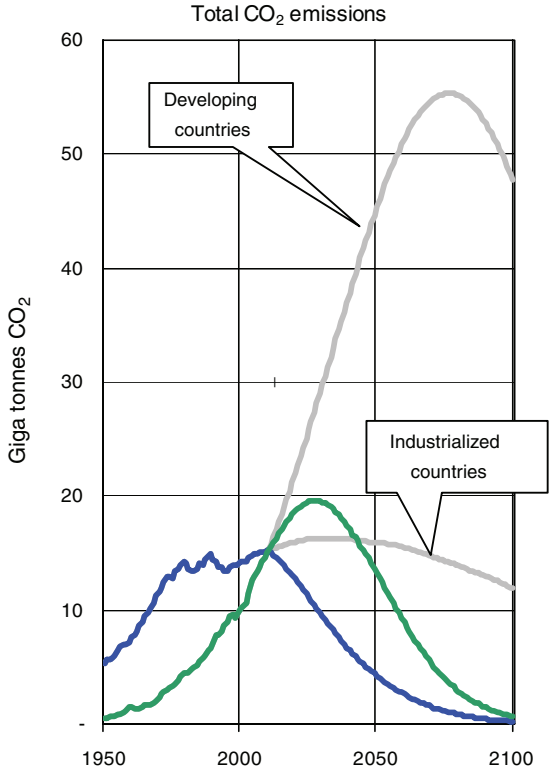

Figure 6. Global CO_2 emissions in developing and industrialized countries in the IPCC reference A1 scenario (grey curves), and in a scenario consistent with the target to limit the increase in global temperature to a maximum of 2 °C over pre-industrial levels (coloured curves). (Source for Figures 5 and 6: see footnote 5.)

VI. Kyoto—A Counterexample?

The Kyoto Protocol has been the subject of much interest and attention. A Google search of the combined phrase "Kyoto Protocol" generates roughly 2.7 million hits, while a search in academic publications at <scholar.google.com> results in roughly 47,300 hits (for comparison, "greenhouse effect" has roughly 60,200 hits in Google Scholar). In addition to the interest, the number of parties that have ratified the Protocol (194 as of late 2009) would seem to contradict the game-theoretic result that such treaties are impossible or difficult to establish with more than a few members. We argue that this largely reflects the lack of true commitment and obligations that ratifying the Protocol actually involves in practice.

For one thing, only the Annex I countries—counting 37 industrialized countries—are committing to abatement targets. Second, these Kyoto commitments—on average aiming for emissions five per cent below 1990 levels in the Annex I countries—are clearly insufficient to rein in anthropogenic climate change. Even in the best case, then, the Protocol should be seen as a first step, or part of an institution-building phase.

Thirdly, Kyoto's targets do not seem to have led to significant reductions in emission levels in many Annex I countries. At first glance, admittedly, the latest figures from the UNFCCC (2008) look quite promising:[22] between 1990 and 2006, aggregate emissions among the 37 Annex I parties had decreased 4.7 per cent, excluding LULUCF. However, there are important nuances behind this seemingly positive picture. While the EIT (economy-in-transition) countries have an aggregate decrease in emissions of some 37 per cent, the other Annex I countries have an increase in aggregate emissions of 9.9 per cent. The reason for the strong reductions in GHG emissions in the EIT parties is not the climate regime but the strongly reduced industrial production which followed in the wake of the collapse of the Eastern European political and economic system. For a truer outcome of the climate regime we must look at emissions from other major Annex I parties. The US has experienced a strong rise in GHG emissions (14.4 per cent), but then the US has not ratified the Protocol. More pertinently, however, ten Kyoto parties have experienced a higher increase in emissions than the US. The most ambitious actor, the EU, seems to be on track to comply with its combined target of 8 per cent, even in the absence of excessive buying of other states' quotas. The main reason for the reduced EU emissions, however, is the strong reductions in the UK and Germany (15.1 and 18.2 per cent, respectively). The EU's result is largely unrelated to the Kyoto Protocol. Germany experienced large emission reductions in the 1990s due to the reunification of Germany, more specifically the closure of inefficient East German energy facilities. The UK reductions are largely due to the replacement, for economic reasons, of coal by reserves of offshore gas.[23] If we look at the original EU-15 countries apart from the UK and Germany, emissions have increased by close to 13 per cent, not far behind the figure for the US.[24] Important nuances are added by controlling for population growth: "Indeed, when one compares trends in per capita emissions, it is striking that the only country to see a decline other than the three 'windfall reductions' (Russia, Germany and the UK) is the U.S., which has been vilified for its decision not to ratify the Kyoto Protocol".[25] Against this background, the 2008 observation made by the UNFCCC's Subsidiary Body for Implementation rings very true: "few if any countries have adopted effective climate policies to date".[26]

Despite the lack of convincing domestic policies, most Annex I countries are expected to deliver on their Kyoto commitments (Canada being a prominent exception). They will do this using LULUCF, CDM credits, and quota-trading to achieve their targets. One way of gauging the size of the commitment made under the Kyoto Protocol, then, is to examine the financial cost that these commitments entail.

[22] UNFCCC Subsidiary Body for Implementation, *National Greenhouse Gas Inventory Data for the Period 1990-2006*, at 9, FCCC/SBI/2008/12 (2008).

[23] Jørgen Wettestad and Siri Hals Butenschøn, *The Increasing British Climate Ambitiousness: A Mere Reflection of "The Dash for Gas"?* Fridtjof Nansen Institute, Lysaker, Norway, FNI Report 3/2000 (2000).

[24] Kathryn Harrison and Lisa McIntosh Sundstrom, *The Comparative Politics of Climate Change*, 7 Global Environmental Politics 1, at 13 (2007).

[25] Ibid.

[26] Supra note 22.

Norway, to take an example, has stated that it aims to fulfill its Kyoto obligations. The country's assigned amount is an annual 50.3 Mt CO_2-eq. over the five-year Kyoto commitment period (2008-2012). According to the Marrakesh Accords, Norway could rely on credits from reforestation of 1.3 Mt per year. Therefore, to the extent Norway's emissions exceed 51.6 Mt CO_2-eq., it must import additional emission allowances. The Norwegian Ministry of Finance estimates the country's annual total GHG emissions to be 57.3 Mt CO_2-eq. per year in the Kyoto period. Hence, it must import permits worth 5.7 Mt per year. If this could fully be accomplished through the CDM,[27] the cost would be roughly 370 million euros—about 0.13 per cent of Norway's GDP—which may be compared with the Norwegian government's expected petroleum income of around 29 *billion* euros in 2010 alone.

The case of Norway illustrates that, for some countries at least, complying with Kyoto carries a low cost. It also reminds us that the business-as-usual path without Kyoto is not the same as a business-as-usual path without climate policy: *domestic* pressure in Norway has caused the government to aim for national emissions ten per cent lower than required by Kyoto, as well as to refrain from counting the reforestation credits. The Kyoto target certainly played into the process of determining the final emission target, but this makes it harder to see the Protocol as a hard constraint that in all cases forces countries to emit less than they otherwise would. Likewise, it could be that the existence of the Protocol increased recent policy ambition in the US ("the rest of the world is doing its bit and we are lagging behind"), but it may also be that it functioned in the US mostly as a symbolic focal point for domestic policy discussions and targets that would have been had in any case as the scientific issues became more decided and the public more informed (through Al Gore's movie "Inconvenient Truth", for example).

VII. Fulfilling Obligations—Political Will and Accepting a Punishment Regime

Turning to compliance, game theory has long been concerned with dynamic consistency and weeding out non-credible solutions to games. A simple example is provided by the doomsday device in the classic Cold-War satire "Dr. Strangelove": the Soviet Union creates a mechanism that automatically triggers subterranean nuclear devices sufficient to kill all surface life in the event of a nuclear attack on the USSR. Great emphasis is placed on the fact that the device is *automatically triggered*, as it would otherwise not be a credible threat: assuming rational decision-makers, threatening to blow up the world if you are attacked is not credible—one no sane person would carry out—and hence one other countries would be justified in ignoring.

Similarly, it is not sufficient for a game theorist that a country ratifies a treaty—it must also be in the country's interest at every later stage to follow through on the commitment it has made. Clearly, there is no police force or higher authority to enforce a treaty among state parties should

[27] Assuming a cost of approximately 13 euros per CER (as was common on the European Climate Exchange for most of 2009).

a party decide not to comply with its commitments. The treaty must contain within itself a mechanism for its own enforcement.

The need for such mechanisms is frequently discussed by economists,[28] but they are frequently absent in real life. The penalty/punishment for a country that fails to achieve the emission levels it has agreed to under the Kyoto Protocol is a good example of this: the country will be asked to abate the shortfall, plus a 30 per cent penalty, in the next commitment period, on top of whatever other abatement the country will commit to in the next period. In other words, a deviating country is supposed to punish itself. As Barrett points out, the "other abatement" the country will commit to in the next period is not fixed, but "subject to the approval of the country having to pay the penalty. That country can therefore insist on a generous cap as a condition for participating, and so get away with paying a 'phantom' penalty. Alternatively, it could ratify the new treaty and then fail to comply again—the current arrangement essentially carries forward the penalty indefinitely".[29]

We are unsure to what extent this theoretical concern is of practical importance. Some economists see it as crucial, but others disagree. For instance, Nobel Laureate Thomas Schelling has stated that he does not "worry much about enforcement. I think that if the major countries reach an agreement they'll do their best to do what they said they would do. [...] when responsible governments make serious commitments, they stick to them, especially when they see other governments sticking to them".[30] This seems reasonable on one level. On the other hand, the climate abatement effort needs to be pursued consistently over the long term, in the face of changing political concerns, changing ideologies in power, etc. It has not proved possible to embed economic incentives in a treaty such that non-compliance is penalized sufficiently to make it undesirable *even for a new administration less concerned with climate change*. The difficulty involved in making China agree (in the Copenhagen Accord) on *voluntary* international verification of national emissions, suggests that a potentially costly "punishment regime" beyond national control is unlikely to happen.

1. Punishing Transgressors—Credible Threats and the Cost of Punishing Others

Just as game theory prompts us to consider countries' incentives to follow through on their obligations, it prompts us to consider the incentives facing the countries *imposing* the penalty/punishment. This point is of little importance for analysing Kyoto. After all, missing incentives to impose punishment do not matter that much when the punishment is insufficiently clear and hard-edged to have an effect to begin with. We include it all the same, though, as it illustrates what may yet prove to be an important requirement for a successful treaty.

[28] Scott Barrett, *Rethinking Global Climate Change Governance* <www.economics-ejournal.org/economics/discussionpapers/2008-31>; Geir B. Asheim and Bjart Holtsmark, *Renegotiation-Proof Climate Agreements with Full Participation: Conditions for Pareto-Efficiency*, 43 Environmental Resource Economics 519 (2009).

[29] Ibid.

[30] Conor Clarke, *Interview with Thomas Schelling*, The Atlantic, 13 July 2009 <http://correspondents.theatlantic.com/conor_clarke/2009/07/an_interview_with_thomas_schelling_part_one.php>.

The "incentive to punish" relates to the dynamic-consistency issue we raised in the previous section: country A will not fear punishment from countries B, C, and D if it will incur high net costs for countries B, C, and D. In that case, country A will view the threat of punishment as non-credible, and will not take it into consideration. Conversely, if we can make it in a country's self-interest to punish parties that fail to live up to their agreed commitments, we make punishment credible. By making punishment credible, we make it in a country's interest to fulfill their agreements. In this way, the treaty has real effects on emissions and actually accomplishes something, making it a treaty that countries can support to limit adverse climate change. The remaining problem then (which we have already considered) is to motivate countries to join rather than free-ride.

For this reason, several economists and political scientists have argued for a better and credible penalty/punishment mechanism in later climate treaties. For instance, a recent pragmatic policy paper (that won the research-paper competition of the Harvard Project on International Climate Agreements) describes a mechanism that would motivate punishers while also motivating countries to join:[31] if you emit more than you are allowed, you pay a penalty per ton of excess GHG, and the penalty is paid out amongst all other treaty members, creating an incentive for others to enforce the "punishments" in order to receive the fine. Knowing that you may benefit from fines paid by others increases incentives to join. And knowing that you could pay the fine should actual abatement turn out to be prohibitively costly makes the fine function as a ceiling on the cost of compliance. This may be contrasted with the Kyoto penalty system, summarized above, where the penalty for insufficient abatement is that the shortfall is slightly increased and added to the country's as-yet-unnegotiated next-period emission target. Will countries play hardball when negotiating the next-period emission targets with nations that did not meet their targets in the previous period? Or will they be soft on those countries? In the absence of any clear benefits from being tough on neighbors and trade-partners, we might expect the softer approach to be preferred.

2. Going Beyond Game Theory

The countries in the game-theoretic models of climate treaties that we have considered are exclusively and unapologetically motivated by national self-interest. In reality, humans have empathy for people in other countries, like to be perceived positively around the world, and so on. Would a country like China, India, or the US in practice abandon, or never join, a treaty because it considered it economically beneficial to be a free-rider instead? We would argue that at least up until now, the answer is yes. Or, if the country did join, it might work to weaken the agreement until there are few economic costs involved in complying, or the abatement targets are no stronger than what domestic pressure and self-interest would have the country accept in any case.

[31] Larry Karp and Jinhua Zhao, *A Proposal for the Design of the Successor to the Kyoto Protocol* (2008) <http://are.berkeley.edu/∼karp/Karp&ZhaoKyotoArchitecture.pdf>.

We agree that the game-theoretic assumption of well-informed and purely self-interested nations is inaccurate as a complete description of the moment-by-moment decisions of most countries. However, this does not mean that an analysis based on this assumption is worthless. For one thing, the current discussions over the role of developing nations and the allocation of costs and emission quotas are clearly motivated by self-interest. The ethical principles are chosen to align with the self-interest. This means that if a proposed treaty goes against a nation's self-interest, the treaty can be rejected for reasons that politicians and voters of that country perceive as moral reasons. The treaty was "unfair" or "unjust" or "deeply flawed" rather than "not sufficiently in line with our coldly calculated economic interests". The rhetoric allows countries to follow self-interest without admitting it to themselves or others. Nevertheless, considering the difference between, for example, India and the US in terms of their *contribution* to the problem so far, as well as their *ability* to deal with the problem, it is understandable that India stresses justice and fairness while there is less room for the US to make comparable moral arguments.

Secondly, a solution to the climate issue requires consistent action over many decades. The public and political interest in the issue, on the other hand, is likely to vary in strength over the period. To ensure that the treaty and abatement efforts continue even in the face of changing administrations, new "threats", and new "global issues", a treaty would need to contain, as mentioned above, sufficient incentives for participation, implementation, and enforcement of the agreed emission targets. The Kyoto Protocol does not have these qualities.

To summarize, then, we would argue that a treaty in the Kyoto mold will not lead to any substantial abatement efforts in practice. Certainly not on the scale required to stabilize atmospheric GHG concentrations at a safe level. The lack of a penalty mechanism with a sting means that ratifying the Protocol has no real cost to a country. The continuing increases in participating countries' GHG emissions is evidence of that. The lack of real consequences or a real cost to joining are, in turn, the reason for the high number of signatories to the Protocol. The EU has seen the Kyoto Protocol as part of an "institution-building phase" to be followed by a tightening of the screws, stronger incentives, and stricter targets. That vision was destroyed at COP 15. No legally binding approach was agreed upon, only a soft political Accord of unclear legal status. At the time of writing (March 2010), it did not seem very likely that some kind of "Kyoto II" would be adopted at COP 16. Thus, the Kyoto Protocol is weak, but the follow-up agreement is likely to be weaker still. Then there are the issues that reduce the intensity and persistence of our motivation: the problem is complex and the important stock/flow dynamic frequently overlooked or misunderstood, current emissions have their main effect several decades down the road, which means that current actions focusing on current events will prioritize adaptation rather than abatement, there is still scientific uncertainty (for instance regarding the level of a "safe" GHG concentration), which makes the importance of early and strong action more difficult to argue, and there is the unavoidable unknowability of the future, which makes it tempting to hope that we will find better, cheaper, ways to solve the problem and will thus be better off dealing with it at some future date.

VIII. Conclusion

The COP 15 outcome is consistent with the slow pace and modest achievements made in the course of twenty years of negotiations. There is an increasing realization that a supplement to the UN approach will be necessary to move the process forward.[32] The UN will of course continue to play an important role in the process. However, as was amply demonstrated in 2009, detailed and complex negotiations cannot be conducted by 192 nations, notwithstanding a thorough and lengthy planning process. As one senior US negotiator stated: "The meeting itself was at best chaotic. We met mostly over night. It seemed like we didn't sleep for two weeks. It seemed a funny way to do things and it showed".[33] The fact that a handful of nations, and most notably China and the US, played a decisive hand in the outcome does not strengthen the future role of UN-based multilateral diplomacy. The G-8 and G-20 fora may come to play a more significant role in the process.

As of today, the less inclusive and more flexible soft-law approaches like that of the APP may offer opportunities, not least as technology is strongly emphasized in these contexts. The APP members are the US, China, Japan, South Korea, Australia, India, and Canada while the seventeen largest economies take part in the MEF. Considering that around twenty countries are responsible for some eighty per cent of the global GHG emissions, the establishment of such smaller negotiation arenas makes sense. So far, however, not much has come out of these initiatives. One reason may be that they were promoted by the second President Bush and thereby strongly associated with the Bush administration's negative stance towards an active climate policy. The more exclusive approaches may, however, be re-energized by the new US administration. An increased fragmentation of the process can therefore be expected, and the "emerging powers" will also play a key role. For example, Brazil, India, China, and South Africa met in New Delhi in January 2010 to co-ordinate their policies.

The intellectual energy expended on the creation of a more effective post-Kyoto treaty is formidable and the importance of innovative institutional design should not be underestimated. However, we have serious doubts that even the cleverest design and the strongest political will on the part of key actors will be sufficient to solve the problem. Over a longer time perspective, the best-case scenario is that the US and the EU push the process forward together, with China taking a similar leading position on behalf of the developing nations. Based on "lessons learned" from COP 15, this scenario is not very likely in the short run. The EU was side-tracked, and due to domestic constraints the US played a rather cautious role. The new veto-player in the game was China, the world's largest emitter. Any agreement is worthless without China, and so it was able to exclude emission goals from the Accord. Moreover, as we have shown in this article, the problem is that even if key Annex I states, the US, and China reduce their emissions very steeply, the effect on the climate system will be exceedingly modest. The long-term challenge is to reduce emissions in all Southern countries, and such a prospect, based on the COP 15 experience, looks

[32] Robert Stavins, *Another Copenhagen Outcome: Serious Questions About the Best Institutional Path Forward*, 5 January 2010 <http://belfercenter.ksg.harvard.edu/analysis/stavins/?p=496>.

[33] *UN Should be Sidelined in Future Climate Talks, says Obama Official*, Guardian.co.uk, 14 January 2010.

bleak. Not all key players of today will be the future's key players. Given the projections for population and economic growth indicated earlier, the achievement of a temperature-increase maximum of two, or even three, degrees seems like a "mission impossible".

Some final words of humility. Game theory shows that any individual country will always find it in its own interest to free-ride, unless this specific act of free-riding has a "multiplier effect" by causing other countries to change their behavior. Some thinkers have argued that higher-level ethical reasoning can transcend this self-interested rationality through, for instance, some kind of Kantian moral principle.[34] If this was empirically important in the context of climate treaties, however, the results of more than twenty years of work on GHG abatement should have been more positive than they are at present. More realistic, perhaps, in the context of international politics, might be a series of global, climate-related disasters that reveal the need for climate action to be obvious and urgent. This might provide the impetus to lift most nations into a climate treaty containing sufficient internal incentives to be self-sustaining when the urgency and public demand for action again fade.

These remarks point to some of the limitations of game theory. In practice, there will be concern for the welfare of people in nations other than one's own. Real nations may deviate in their actions from game-theoretic predictions. This could be due to cultural, emotional, or cognitive biases or other factors, and deviations of this kind could make climate treaties more, as well as less, likely than game theory predicts. Finally, some researchers (notably Parkash Chandler and Henry Tulkens) have argued that broad, effective, climate coalitions *can* emerge even out of self-interested nations.[35]

Few analysts in 1910 had much of an idea what the world would look like in 1960 or 2010. Similarly, we have no crystal ball that can tell us what the world will look like in fifty or one hundred years. The technology optimists might be right: new technology might provide the much needed silver bullet. We might develop new, clean-energy technology that is cheaper than fossil fuels and wins out even without abatement policies such as carbon taxes. We might find ways of taking carbon cheaply out of the atmosphere, or safe and acceptable geoengineering technologies that counteract the effects of high GHG concentrations. And so on. The likelihood of that scenario, however, is impossible to estimate.

[34] Amartya K. Sen, *Rationality and Morality: A reply*, 11 Erkenntnis 225 (1977).

[35] For example, Parkash Chander, *The Kyoto Protocol: An Economic and Game Theoretic Interpretation*, *in* Public Goods, Environmental Externalities and Fiscal Competition (Parkash Chander et al., eds., 2006).