An Innovative Policy Approach to Solve the Global Climate Issue

Stephen C Peck, Flèche, Palo Alto, California, USA
Thomas J. Teisberg, Teisberg Associates, Virginia, USA
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Introduction

Reflecting world-wide concern about the possibility and impacts of climate change, the text of the United Nations Framework Convention on Climate Change (UNFCC) was adopted at the United Nations Headquarters, New York on May 9, 1992. By June 1993, it had received 166 signatures and it entered into force on 21 March, 1994.

Article 2 of the Convention states:

"The ultimate objective…..is to achieve…stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner".

The text of the Protocol to the UNFCC was adopted at the third session of the Conference of the Parties in Kyoto, Japan, on 11 December 1997. By 15 March 1999 the Protocol had received 84 signatures but had not entered into force because it had not yet been signed by Annex I parties accounting for at least 55% of total carbon dioxide equivalent emissions.

The key text of the Kyoto Protocol is the first part of Article 3:

"The Parties included in Annex I shall…..ensure that their aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases…do not exceed their assigned amounts ….with a view to reducing their overall emissions of such gases by at least 5 per cent below 1990 levels in the commitment period 2008 to 2012".

Note the distinction between the UNFCC and the Protocol. The former deals primarily with stocks in the atmosphere about a century hence, the latter with near term five year flows. Given the fact that, for various reasons, it is easier to achieve a target stock in the atmosphere rather than an immediate stringent flow reduction, one can only speculate why the delegates chose to focus on flows to the atmosphere of greenhouse gases between 2008 and 2012.

[1] Correspondence to lead author Peck_Stephen@msn.com.

Many Annex I nations – especially those making a transition from coal to gas for other reasons - are inclined to implement the Kyoto Protocol for the first commitment period – but they have concerns about the as yet undecided reductions to be mandated in the second period. The US with its heavy and unchanging commitment to coal at the current time has stated it will not sign the Kyoto Protocol but instead rely on a continuation of its historically declining carbon intensity of energy.

However negotiations for the second commitment period are rapidly approaching and the large emitter nations might wish to be armed with a thought-out policy with a timetable extending beyond 2017 for emissions of greenhouse gases whose damage is largely associated with the levels of atmospheric stocks (i.e. concentrations) rather than the current emission rates.

The global climate issue is in a class of problems associated with common property rights (CPR's). Ostrom et. al.[2] have surveyed many arrangements for managing CPR's at the local and regional level and have found surprising successes: however the challenge of constructing management systems for global CPR's are manifold. Generally they include; a) the large number of participants, b) a high degree of cultural diversity, c) complications associated with interlinked CPR's (e.g. leaving room for nature on the one hand, while keeping people apart to prevent the potential spread of infectious disease), d) accelerating rates of change, e) the common requirement of unanimous agreement as a collective choice rule, and f) there is only one globe with which to experiment

Notwithstanding these difficulties, we describe below a policy which seems to be consistent with the UNFCC with its focus on atmospheric concentrations[3]. The

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[2] E. Ostrom et al. Revisiting the Commons: Local Lessons, Global Challenges. Science 4/9/99

[3] Many papers have analyzed long term approaches to manage climate change. Among these are W.D. Nordhaus, To Slow or Not to Slow, American Economic Review 1982, Peck S C and T J Teisberg "CETA: A Model for Carbon Emissions Trajectory Assessment," The Energy Journal, 13, 1, 55-77, 1992,; Wigley T. M. L., R. G. Richels and J. A. Edmonds, "Economic and Environmental Choices in the Stabilization of Atmospheric CO_2 Concentrations", Nature, 379, 18, 1996. More policy related papers are Kosobud R.F. et al."Tradable Cumulative Carbon Dioxide Permits and Global Warming Control." The Energy Journal, 15, 2, 213-232, 1994. See also McKibbin W.J. and P. J.Wilcoxen, "A Better Way to Slow Global Climate Change. Brookings Policy Brief 17 (Washington, DC, The Brookings Institution). Recently a strong argument for a long term climate policy has been advanced in K. Hasselmann et al. in "The Case for Long Term Mitigation of Anthropogenic Climate Change." European Climate Forum Draft Working Paper, February 2003.

Kyoto Protocol, a significant achievement of international collaboration, could be seen as a first step of this new policy. Our suggested policy, to be implemented possibly soon after 2102, may be viewed in a second step in a contingent strategy for managing the global climate problem that will evolve over the next century and beyond as we learn more about the science of the issue, about the appropriate mitigation and capture technologies for greenhouse gases and of what types of policies do and do not work.

Proposal Provides Timing Flexibility and Geographical Flexibility

Emission reduction flexibility in time and space (geography) are necessary conditions for a least cost intertemporal world climate control policy. Very simply our proposal is that a provisional atmospheric target be determined for each of the six greenhouse gases. Suppose that the targets were intended to be achieved by 2070. Then a permit would be needed to emit *the equivalent of* a ton of each of the important gases in 2070 – probably carbon dioxide, methane and nitrous oxide – the other gases would likely be handled by more conventional command and control methods. The permits would be designed so that they accounted for the atmospheric depreciation of each gas. Since that carbon dioxide (CO_2), which is above preindustrial levels, is absorbed by the oceans from the atmosphere at a rate of about 1% annually the carbon dioxide permit would allow the emission of 1 ton of carbon in 2070, 1.01 tons in 2069, 1.01^2 in 2068 and 1.01^{60} (1.71) tons in 2010. Each permit could be used once at any time between 2010 and 2070 and then would be surrendered.

We propose an initial focus on the seven major nations or groups that emit or will emit large amounts of CO_2 and presumably of the other five greenhouse gases (US, Western Europe, Japan, Russia, China, India, and Brazil). The number of permits for each of the gases to be used worldwide to achieve the target can be estimated[4] and the major emitting nations could act unilaterally - but subject to discussion and negotiation with the others - in deciding how many of the permits to take. As a general guideline, each major emitting nation or group should take sufficient permits for its projected emissions under a least cost intertemporal world plan to achieve a given terminal atmospheric concentration.[5]

To stabilize atmospheric concentrations of CO_2, for example, at about 550 parts per million in the atmosphere (twice the preindustrial level), 425 billion carbon dioxide permits (measured in equivalent tons of 2070 carbon) could be issued

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[4] Note that we do not use carbon equivalents for the other gases. We prefer to model atmospheric chemical dynamics more directly because we believe it is enables the achievement of a cheaper long run strategy.

[5] If a populous nation, for instance Indonesia, were to develop very rapidly, it could be added to the initial Group of Seven. Once the Group of Seven had established the efficiency regime, it is envisaged that other nations would also reduce their greenhouse gas emissions due to the incentives inherent in doing so - which are articulated later in the paper.

between 2010 and 2070. The United States, currently likely to emit about 20% of the world total in a least cost intertemporal strategy, would take 85 billion permits (0.2*425), or 1.4 billion permits per year for each of the sixty years from 2010 to 2070, equivalent to much less than its future average emissions in a CO_2 unconstrained world. Because the timing of permit use is not constrained, it would be possible to continue the use for a limited period of existing equipment which emits sizeable amounts of CO_2. Those Annex I nations that have already or are likely to sign the Kyoto Protocol might well pursue a similar strategy[6].

Each major nation or group with a well developed legal and regulatory regime would always have 20 years worth of permits outstanding in private hands for each of the major gases included in the Kyoto Protocol for the period of time until the atmospheric concentrations of these gases stabilize (this would have to be modified in the last 20 of the 60 years in our example). Thus some certainty about the future could be provided to firms and households investing in (usually) capital intensive new technology intended to reduce emissions of greenhouse gases. Within each nation or group, these permits would be tradable across sectors and time; however due to the non-uniformity of national legal systems, they would not be tradable by private parties in nations/groups that did not have compatible legal systems[7]. However any nation's permits could be bought as investments by foreigners.

Governments would enforce the rule that any entity emitting a ton equivalent of one of the gases would have to give up a permit. They would also provide permits for credible sequestration projects that act, essentially, to reduce the concentration in the atmosphere of CO_2 or other greenhouse gases. Thus farmers and others would be compensated in cash for sequestration activities. In addition if there were forest fires that caused the emission of more than an expected amount of carbon dioxide, the owners of the resource would have to purchase emission permits. This would provide an additional incentive for the proper management of, for instance, the US national forests in the West, which seem to burn uncontrollably most summers.

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[6] Each of the seven nations would be given the most efficient number of permits to auction. However each of those nations' governments would not necessarily receive income equal to its permit revenue. A richer nation of the Group of Seven could for instance give poorer members of the Group some portion of its auction revenue. Poorer members of the Group of Seven would not necessarily auction all of their permits to domestic nationals. Some could be bought and held as financial assets by entities from the richer nations.

[7] Note that we do not rule out such trading *a priori*. The United States and Europe might find initially such uniformity in their legal systems that they might decide to allow private trading of permits and the use of European permits to offset American emissions or vice versa. Later in the paper we argue that, over time, other nations might join this arrangement if it was judged, in conjunction with the existing participants, that their legal systems had developed to the required standard of comparability and excellence.

Governments, after issuing 20 years' permits to establish the markets, would subsequently issue, every year, a number of permits for each gas equal to about one year's use. If scientific research showed that the target concentration was not correct, the annual number of permits issued could be altered. If an increase in target atmospheric concentrations was required, that could be handled by changes to the annual flow of permits into the market. Since such an increase could have the effect of driving down the permit price, it might be necessary for a government to subsidize the current permit holders from tax revenues in order to mollify their likely concerns associated with having some of the capital value of their holdings destroyed by government action. This policy could be unattractive to taxpayers. If a major reduction in target concentration of some gases was required, each Government could purchase permits in a similar fashion to Open Market operations by Central Banks. Funds for this might also have to be provided from new tax revenue. Otherwise Governments would have a limited role to play and the private markets for goods and capital, where they exist, would be relied upon to solve the climate problem - just as they solve, once appropriate property rights are established, most other problems involving the allocation and consumption of scarce goods. This would essentially solve the climate problem by turning it from an environmental issue of concern to an economic question.

Some auction revenue may be used to render much less risky and hence more attractive those investments in capital-intensive technologies that produce energy with low greenhouse gas emissions. For instance, such payments could be used to insure the investors in Renewables and Nuclear against an unexpected fall in the price of natural gas and hence electricity. Auction revenue could be used to reduce other taxes.

Intertemporal behavior of the permits' prices and a new political interest

The permits are financial assets whose price would be expected to rise, ex ante, at the real interest rate (say 5%) each year, since they pay no dividends and they need to be as attractive to hold as other equivalent financial assets. Because of the permit design, the marginal cost of the removal of one ton of gas would rise at the sum of the real interest rate and the rate of depreciation for each gas – for instance 5% plus 1% or 6% for CO_2. This generates the least cost pattern of emissions reductions over time as was shown by Hotelling[8]. Peck and Teisberg[9] calculated (conditional on the carbon cycle model used and on assumptions about the price of backstop technologies, real income growth etc.) that the price of a CO_2 permit (measured as one ton equivalent of carbon emissions in 2070) in

[8] Harold Hotelling. Economics of Exhaustible Resources, Journal of Political Economy, 1931.

[9] Stephen C Peck and Thomas J Teisberg. Securitizing the Environment: A Property Rights Approach to Managing Climate Change; Proceedings of an International Symposium on Environmental Issues held in Wageningen, Holland, June 6 & 7, 2002; forthcoming.

2010 would be about $11.25. This translates to a marginal cost of emission reduction in 2010 of $11.25/1.71 or $6.50/ton. If twenty years worth of permits were issued by the Group of Seven in 2010 the market value of outstanding permits would be about 140 billion permits times $11 per permit or about $1.5 thousand billion (trillion). In 2050, there would still be about 140 billion permits outstanding with a current price of somewhat under $100 per permit for a capital value of $13 thousand million (trillion). The value would approach zero in 2070 as all the permits were used up. It would then be necessary to enter a new regime to maintain the CO_2 concentration at 550 parts per million. If in this new regime, it were true that permits for 4 billion tons a year could be issued and the market price after 2070 would lie between $100 and $200 per ton, then the annual permit issue would be valued at between $400 and $ 800 billion annually.

Note that these very large asset values create an interest in the preservation of the program of atmospheric stabilization. To repeat and emphasize a point made above, by the middle of the next century, there will be asset holders with over $10 trillion pushing for continuation of the program just as permit prices start to rise to levels that are likely to be hard for those companies, which still emit greenhouse gases, to pay and they will start to push back to weaken the program. These countervailing pressures are likely to lead to a reasonable social compromise relative to a situation where only the greenhouse gas emitting companies have a strong financial interest.

Government incentives to reduce emissions

In 2010, given our assumptions, the US Government would be empowered to issue twenty years worth of CO_2 permits - about 1.4 billion permits a year. We estimated the market value of these permits to be around $11.25 each. Hence if it were to auction all the CO_2 permits, the US government would generate 20 years times 1.4 billion permits per year times 11 dollars per permit or $310 billion. In subsequent years, the US Government could auction 1.4 billion permits per year at continually higher market-determined prices. With prices doubling every 12 years, in 2034, the annual auction revenue could be $45 per permit times 1.4 billion permits or $63 billion. These revenues from auctioning all the permits are very significant sums for the US. We have carried out similar calculations with results even larger in comparison with their GNP for the non-Annex One nations China, India and Brazil. By auctioning twenty years worth of permits in the first year, these countries would be generating revenues equal to about 15% of their annual GNP's. However, in order to maximize permit revenue, their governments might decide to issue less that twenty years worth of permits for the following reason.

In order to sell a large number of permits, a nation such as Brazil would almost certainly have to attract foreign buyers for a substantial portion of the permits. It will have to make a persuasive case that every entity emitting CO_2 in Brazil would require to give up a permit. Now, selling twenty years worth of permits on the

basis of a promise is not likely to convince the foreign buyers; they are more likely to be convinced by a well functioning reporting, regulation and permit surrender scheme for those who emit. Initially the Brazilian government might issue only four years worth of permits arguing that such a number of permits might attract the highest price, and that this higher price would offset the difficulties caused to investors in CO_2 reducing technologies in Brazil who would probably prefer a larger stock of permits because of the security of a large outstanding stock provides for the capital investments needed to reduce greenhouse gas emissions[10]

If, contrary to expectations, major nations/groups do not join the coalition, then the existing coalition members could raise the climate concentration ceiling and issue more permits annually so as to avoid their own permit prices from rising too much and disadvantaging their industries relative to those of the non-participants. Thus an "off-ramp" is available, similar to other proposals[11]. As mentioned previously the likelihood of the off-ramp being taken depends on the willingness of the Government to state credibly ex ante and then to use tax revenues to compensate those whose permit wealth is destroyed by such a policy.

Basis for permit allocation

As mentioned previously, a general guideline is that each major emitting nation or group should take sufficient permits for its projected emissions under a least cost intertemporal world plan to achieve a given terminal atmospheric concentration. This is an *efficiency* criterion not one of *equity* in contrast to most of the international discussion of this issue. This view changes the analytical interest to one focused on which nations would be most efficient in creating and/or deploying new greenhouse gas reducing technologies – they should presumably receive relatively few permits. It also attracts attention to the fact that while developed nations with their large scientific establishments may be the most efficient in *creating* new low greenhouse gas emitting technologies, it may be the developing countries with their massive growth that will be most efficient in *deploying* new technologies.

Initially the efficient allocation of permits could be decided by conducting an exercise like those carried out by the Energy Modeling Forum[12] in which experts,

[10] Most likely each nation, so as not to harm its energy intensive industries, would auction only some of the permits and give others away.

[11] Raymond Kopp, Richard Morgenstern and William Pizer, "Something for Everyone: A Climate Policy That Both Environmentalists and Industry Can Live With" Resources for the Future, Washington, D.C.

[12] The Energy Modeling Forum is an entity set up about 25 years ago at Stanford University by Martin Greenberger then of the Electric Power Research Institute and now of UCLA and William

energy modelers and policy-makers primarily, but not exclusively, from the seven large regions would be brought together to identify what they believed to be the optimal intertemporal allocation of permits. Because of a myriad of uncertainties, those estimates will be wrong and by 2020 or 2030, that reality will be reflected in different permit prices for the various greenhouse gases in the seven regions. Some transfer of permits from the low price regions to the high price regions will be desirable from an efficiency viewpoint. However there is an incentive issue if too large a transfer of permits is expected as of 2010, because each region may then have little incentive to invest during the period 2010 to 2030 in greenhouse gas emission reduction technology - if it is confident that any consequent rise in permit price will be compensated by a grant of permits from the other regions which have a lower permit price, partly because they have invested in low greenhouse gas emitting technology. Some of our current research efforts focus on the tradeoff between the costs of permit allocation under relative ignorance in 2010, versus the investment disincentive costs of low permit price regions being expected to donate permits to high permit price regions in 2030, given the likelihood of somewhat less ignorance and enhanced modeling capability in 2030.

There is an alternative resolution of this problem. That is to divorce the issue of the number of permits a country has from the price of the permit in that country. This would tend to happen in a more global permit market rather than in the seven loosely linked permit programs which are to be initiated in 2010. Recall that governments of countries such as Brazil would need in 2010 and subsequently to attract foreign investors so they would purchase Brazilian permits. To do so they would need to show that they are capable and willing to administer an honest emissions reduction scheme. This is precisely the same demonstration they would need to make in order to enter a more global permit market[13].

May a virtuous cascade cause US to acquire inadvertently a climate policy?

Many US States (and Cities) are currently running a large budget deficit due to the explosion in commitments that took place in the last boom and the current recession. There are indications that to enhance their budgets some state finance directors are considering the issuance of state climate permits which would be required by any entity that emitted greenhouse gases in their State. If a State which emitted 5% of US carbon dioxide issued 20 years worth of permits, it has the potential to raise 5% of $310 billion or around $15 billion. If it were to wait for the Federal Government to initiate its own climate program, the State

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Hogan then of Stanford and now of Harvard. The current Director is John Weyant of Stanford University. Recently the European Climate Forum (ECF) has been created with Carlo Jaeger of PIK as the chair of its Academic Committee. The ECF could be also a leader or co-leader in such an exercise.

[13] I am indebted to Denny Ellerman of MIT for an interesting discussion of the importance to aiming ultimately towards a global permit scheme within which the allocation of permits would not affect the efficiency of the scheme because the permit price would be the same everywhere.

receives nothing. Preliminary legal research suggests that if the State legislation made no mention of any international purpose in its reduction of greenhouse gases, then such an issuance might not be successfully challenged by the Federal Government.

But this strategy is not riskless, as can be seen by considering how State A's permits would be priced in an auction. Potential bidders would have to consider the following risks: a) neighboring State B would not implement its own permit program thus causing electricity generation to be switched to State B, and causing a drop in demand and price for State A's permits, b) the Federal Government might subsequently drive down the price of State A's permits by issuing its own permits. Of course it is possible that a) neighboring State B would enter into a compact with State A to have its own permit program and b) the Federal Government could convert a patchwork quilt of State programs into a Federal program by auctioning Federal permits and using some of the proceeds to purchase permits from individuals who had purchased State permits; in this case the States would retain the original auction money.

Permits that allow an intertemporal benefit cost solution

Up to now we have assumed that the objective is to not to exceed a given concentration of each greenhouse gas in the atmosphere in the most *cost effective* manner. However since we are presumably constraining the growth of greenhouse gases because we want to achieve a reduction in the harm done by their accumulation in the atmosphere, we may want to extend the reach of the permit program to achieve an *optimal intertemporal cost benefit* solution.

Consider how this may be done for carbon dioxide alone. It requires the creation and auction of permits which pay dividends in addition to yielding a capital appreciation. The dividend paid to a holder of a permit in a given year represents the benefit of not using the permit in that year – which is the damage avoided by not emitting the gas.

To create markets, the optimal stock of permits would be determined for carbon dioxide and distributed to the participating regions, and the permit for the carbon dioxide mass above preindustrial level is specified to depreciate at the appropriate rate until the steady state is reached – and each region's government pays a dividend which depends on the global atmospheric temperature. The dividend has the effect of reducing the rate of price appreciation of a permit needed to bring its rate of return up to the real interest rate and hence of causing the permit price to start at a higher level in 2010. Furthermore since temperature rises over time, the dividend also rises causing the rate of permit price appreciation to decline until the steady state is reached at which time the permit price is constant and the entire return on the permit comes in the form of a

dividend yield representing the damage foregone by not emitting the marginal ton of the gas[14].

Extension to the other major greenhouse gases

Up to this point, we have concentrated our exposition on carbon dioxide in each of the seven major regions. We are now working to extend the approach more precisely to the most important of the other greenhouse gases. Many of these contain carbon atoms, e.g. HFC, and in the process of breakdown into carbon dioxide create other climate forcing gases which are not primary emissions[15]. For instance methane, CH_4, is a potent greenhouse gas itself, although with a high rate of breakdown (about 10% a year), and a producer of CO_2, tropospheric ozone and stratospheric moisture all of which have warming effects as a result of the breakdown.

Our approach in this case would be to minimize the sum of a) emissions control costs which depend on the amount of emissions reduction and b) the climate change damage costs which depend on the actual rise in global temperature, itself reacting with a lag to the committed rise in global temperature, dependent on the concentration excesses of the greenhouse gases relative to preindustrial levels.

In this case, first a permit is created for the amount of actual temperature change. This permit depreciates at the rate of lag of actual temperature behind committed temperature (thought to be about 2% a year). This permit yields a dividend dependent on the temperature rise relative to preindustrial, and the sum of the capital appreciation rate plus the dividend yield equals the real rate of interest.

For carbon dioxide, a permit is created which depreciates from the atmosphere at about 1%, the same rate as the gas itself. A dividend is paid to the holder of

[14] The dividend could be paid by the issuing government or a private entity could sell securities to the government which carried the obligation to pay the dividend according to some specified rule dependent say on the estimated climate change damage function.

[15] Some points of relevance are made in J. Reilly, R.G. Prinn et al. "Multi-Gas Assessment of the Kyoto Protocol." Joint Program on the Science and Policy of Global Change. Massachusetts Institute of Technology. January 1999.

carbon dioxide permit which depends on the price of the temperature permit and on some features specific to carbon dioxide.

For methane, a permit is created which depreciates at the same rate as the gas itself depreciates (thought to be 10% annually). The methane permit pays a dividend which depends on the price of the temperature permit and on some features specific to methane. But in addition, the emitter of methane must hold some carbon dioxide permits to reflect the fact methane breaks down into carbon dioxide, another greenhouse gas. In addition if we consider the other breakdown products of methane important products (e.g. Stratospheric water vapor or Tropospheric ozone), it is necessary to create permits for these gases and for them to be held and surrendered to reflect the creation of these breakdown products.

Including the Nations Vulnerable to Climate Change

Up to now we have focused our discussion primarily on the large emitter nations. Generally the richer a nation is, the more able it is able to manage and adapt to whatever climate change occurs. However there is a set of nations, many in mid to Southern Africa and others which are island states that are particularly susceptible to climate change.

For these nations we suggest setting up a second and larger negotiating group 1) to focus on climate change adaptation approaches with desirable features, 2) to recommend how much adaptation should be funded by the Group of Seven possibly from the large amounts of government revenue that will be generated from the permit auctions, 3) to hold discussions with the Group of Seven about what the most appropriate concentration targets are for each of the gases or, perhaps equivalently, what should be the target amount of global climate temperature increase, and 4) for advice on setting up their own national emission trading systems which would be attractive to their governments for the same reason as for the Seven, namely as massive revenue generators.

It has been shown that for the global climate change problem, the optimal amount of greenhouse gas reduction is almost independent of who pays[16]. Thus the distinction between the efficiency aspects of the world intertemporal emission strategy as a focus of the first group and the distributional aspects as the focus of the second group has conceptual validity. In addition part of the permit revenue might be used to fund some of the goals (e.g. clean water for more of the world's population) recently adopted at the World Summit on Sustainable Development held in Johannesburg, South Africa.

[16] H.P. Chao and S.C. Peck, "Greenhouse Gas Abatement: How much? Who pays?" Resource & Energy Economics, 22 1-20, 2000

A Note on Uncertainty

Although the future is uncertain, and that uncertainty has been recognized explicitly in this paper, the analytical framework employed has been one of certainty. Thus when we say that the permit price will rise at the real rate of interest, this is true only in an ex ante sense. Obviously the future in 2030 will not be the same future as that precisely envisaged in 2010. In other words the ex post outcomes will differ from the ex ante anticipations. So, in this explanatory paper there is a little bit of a mismatch between the verbal descriptions and the formal models employed.

This is not, of course, necessary in that there are models of markets filled with actors who have current expectations and who make exchanges based on those beliefs, and then enter the next stage of the future with asset situations determined by those decisions. Once the next stage of the future is revealed and the state of expectations of the actors changes, another set of exchanges is made. This type of approach may be adopted in our future work because the global climate issue has manifold and changing circumstances ranging from how much it costs to remove emissions of each of the key gases, to who will participate in a world wide agreement, to what policy will be adopted, to what does determine the concentrations of all the greenhouse gases in the atmosphere, to what is the likely effect of those increased concentrations on global temperature and on local ecosystems and health outcomes.

Conclusion

A system for international control of greenhouse gases has been described that:

- Starts off inexpensive and increases in cost relatively slowly (initial year jump-up in gasoline and natural gas prices would hardly be noticeable).
- Is likely to induce all major emitter nations, including the US and the major developing nations Brazil, China and India, to participate.

It does this by:

- Focusing on stocks of greenhouse gases in the atmosphere (consistent with the UN Framework Convention on Climate Change).
- Generating significant auction revenues and an incentive for adequate self policing for the governments that issue the permits.
- Establishing appropriate property rights, hence enabling maximum advantage to be taken of the capital and goods markets.
- Creating a wealthy class of individuals and companies with a strong financial interest in the integrity of the global atmosphere.
- Reducing governments' participation to the necessary minimum of issuing permits and policing the permits markets.
- Enabling the permits to be used at any time between issue and the end of the period at which the target steady state is achieved (perhaps seventy years).

- Engaging the seven largest emitter nations/groups in discussions of the most efficient ways to reduce emissions.
- Involving the poorer and more vulnerable nations in discussions of how to adapt to climate change and how much compensation should be awarded for the damage to be done to their societies.
- Allowing for interactions between the two groups on the amount of global climate change to aim for.
- Providing income to farmers and other sequesterors of greenhouse gases.
- Acting to maintain forests, so they do not burn disastrously.

Endnote

The elements of this paper have benefited greatly from having been discussed with many people in many meetings. We are grateful to the participants for all the issued raised and suggestions made. There has been virtually no discussion in which our ideas have not been augmented by such interaction[17].

[17] Individuals from numerous organizations have heard presentations and discussed this proposal, generally making suggestions for improvement. Without implying endorsement by any, they include:

- International – BP, Exxon, Shell
- US - State Department., Council of Economic Advisors, Environmental Protection Agency, Edison Electric Institute Climate Committee, Association of Edison Illuminating Companies Generation Committee, Generation and Transmission Managers Committee, several large individual utilities, assorted academics, EPA Contractors, NGO's, Natsource, Resources for the Future
- Europe (including Russia) – European Conference Board Committees on Environment and on Health and Safety, Eurelectric Climate Committee, Electricité de France, ENEL of Italy, RWE of Germany, Scottish Power, Texas Utilities - Europe, Potsdam Climate Institute
- China – Environmental Protection Agency, China Light and Power
- Japan – Tokyo Electric Power Company, KANSAI
- India and Brazil – US academic contacts so far