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The Case for Charges on Greenhouse Gas Emissions

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THE HARVARD PROJECT ON INTERNATIONAL CLIMATE AGREEMENTS

The goal of the Harvard Project on International Climate Agreements is to help identify key design elements of a scientifically sound, economically rational, and politically pragmatic post-2012 international policy architecture for global climate change. It draws upon leading thinkers from academia, private industry, government, and non-governmental organizations from around the world to construct a small set of promising policy frameworks and then disseminate and discuss the design elements and frameworks with decision-makers. The Project is co-directed by Robert N. Stavins, Albert Pratt Professor of Business and Government, John F. Kennedy School of Government, Harvard University, and Joseph E. Aldy, Fellow, Resources for the Future. For more information, see the Project's website:
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Abstract

The proposal discussed in this paper is to levy a common charge on all emissions of greenhouse gases, worldwide. All countries would be covered in principle, but the proposal could be implemented with a much smaller number of countries, provided they covered most of the emissions. While all greenhouse gases should in principle be covered, this paper will address mainly carbon dioxide, quantitatively the most important greenhouse gas; extensions to other greenhouse gases could be made with little or (in the case of methane) much difficulty. The charge would be internationally adjusted from time to time, and each country would collect and keep the revenue it generated.

This paper will discuss in turn the motivation for such a proposal, how it would be implemented, its likely economic effects, the relationship to energy security, the possibility of mixing an emission charge with other schemes to limit emissions, especially "cap-and-trade" schemes, and the negotiability of such an agreement.

The Case for Charges on Greenhouse Gas Emissions

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The Proposal

The proposal discussed in this paper is to levy a common charge on all emissions of greenhouse gases, worldwide. All countries would be covered in principle, but the proposal could be implemented with a much smaller number of countries, provided they covered most of the emissions. While all greenhouse gases should in principle be covered, this paper will address mainly carbon dioxide, quantitatively the most important greenhouse gas; extensions to other greenhouse gases could be made with little or (in the case of methane) much difficulty. The charge would be internationally adjusted from time to time, and each country would collect and keep the revenue it generated.

This paper will discuss in turn the motivation for such a proposal, how it would be implemented, its likely economic effects, the relationship to energy security, the possibility of mixing an emission charge with other schemes to limit emissions, especially "cap-and-trade" schemes, and the negotiability of such an agreement.

Motivation

Table 1 reports the worldwide growth in carbon dioxide emissions generated by the use of marketable energy (mainly fossil fuels) in 1990, the base year for the Kyoto Protocol, for 2005, and projections to 2010 (the mid-point of the target period of the Kyoto Protocol), 2020, and 2030. These projections have been made by the US Department of Energy in its 2008 annual review of the international energy outlook, as a by-product of its assessment of the future demand for energy. The projections are based on assumptions about economic growth in different parts of the world, the relation of demand for different types of energy

[1] I am grateful to Joe Aldy and Rob Stavins for helpful comments on an early draft.

(e.g., electricity, transportation) to economic growth as a function of stage of development, and a price of oil that gradually declines from the high levels of mid-2008 to $70 a barrel in 2015, and then remains roughly unchanged in real terms until 2030. Higher and lower price scenarios are also addressed. The world economy is assumed to achieve an average annual growth of 3.0 percent over the projection period, with countries weighted by their GDP at market exchange rates in 2000, and on average world demand for energy will grow by 1.6 percent a year (liquid fuels by 1.2 percent, coal by 2.0 percent).

Table 1
World Carbon Dioxide Emissions[a]
(billion metric tons)

	1990	2005	2010	2020	2030
World	21.2	28.1	31.1	37.0	42.3
North America	5.8	7.0	7.1	7.6	8.3
USA	5.0	6.0	6.0	6.4	6.9
OECD Europe	4.1	4.4	4.5	4.8	4.8
OECD Asia	1.5	2.2	2.2	2.3	2.4
Japan	1.0	1.2	1.2	1.2	1.2
Total OECD	11.4	13.6	13.8	14.7	15.5
Total Non-OECD	9.8	14.5	17.3	22.3	26.8
Russia	2.4	1.7	1.8	2.0	2.1
China	2.2	5.3	6.9	9.5	12.0
India	0.6	1.2	1.3	1.8	2.2
Brazil	0.2	0.4	0.5	0.5	0.6
Other	4.4	5.9	6.8	8.5	9.8

[a] From fossil fuels
Source: EIA. International Energy Outlook, 2008, Table A10

It can been seen in Table 1 that carbon dioxide emissions grow steadily over the period, doubling 1990 levels by 2030. Also noteworthy is that emissions from non-OECD countries (mostly developing countries) alone by 2020 exceed the world levels of 1990. Put another way, the rich countries could have cut their emissions to zero and the world would be back where it started in 1990, with a level of emissions that was deemed to be too high. It should be noted that Table 1 reports emissions only from consumption of marketable fuels; the important emissions from tropical deforestation are not included, and would raise the non-OECD emissions throughout. In short, seriously addressing carbon dioxide emissions requires a worldwide approach, not one limited to today's rich countries. Moreover, if some significant countries are excluded from coverage for any length of time, fossil-fuel-using production will tend to migrate to those countries, thus undermining the efforts of countries that are covered by any arrangement to mitigate GHG emissions.

Decisions to consume goods and services made with fossil fuels are made by over a billion households and firms in the world. The best and indeed the only way to reach all these decision makers is through the prices they must pay. If we are to reduce CO_2-emitting activities, we must raise the prices of those activities. Levying a charge on CO_2 emissions does that directly. A cap-and-trade (CAT) scheme, under which allowable emissions are capped and tradable emission permits are issued, does so indirectly, if less transparently (as emphasized by Williamson, 2008). In the absence of perfect substitutes for CO_2-emitting activities – and none are presently or prospectively available in the near future – the permits will have value that will be priced into the CO_2-emitting goods and services, resulting in higher prices.

As noted above, decision makers around the world must be reached, not just those in today's rich countries. A CAT scheme has two compelling disadvantages on a global scale. First, it will probably be impossible to negotiate meaningful, effective emission limits among all countries. Developing countries will understandably resist any emission ceiling that they believe will limit their economic development, i.e. their rate of economic growth. They will argue that experience of other, more developed countries included a rapid growth in demand for energy based on fossil fuels, and they will not agree to limits on their potential growth. Emission ceilings could no doubt be negotiated, but their global total would be too great to cut emissions; developed countries in turn are not likely to accept cuts so deep as to jeopardize current standards of living, especially when developing countries are unwilling to accept meaningful ceilings.

Second, under a meaningful CAT scheme governments will need to allocate valuable emission permits to domestic firms or residents. This will be an open invitation to favoritism in many countries or, to put it less politely, it will unavoidably foster rampant corruption. Do we really want climate policy to be a handmaiden to corruption around the world? Under international trading, ordinary citizens in rich countries will be charged for their consumption of CO_2-emitting activities, or they will (indirectly) purchase emission rights from the often rich cronies of political leaders in developing countries. A universal CO_2 charge would avoid such problematic and politically indefensible transfers.

Modus Operandi

Several practical issues must be addressed in considering a "carbon" charge: coverage, geographic, sectoral, and greenhouse gases; periodic review; compliance; enforcement; and offset credits.

Geographic coverage should be as broad as possible. Climate change is a global problem, resulting from greenhouse gas emissions wherever they occur. The solution also needs to be global. The initial scheme need not cover literally all countries; three or four dozen countries account for the vast majority of emissions. But key developing countries must be included. As suggested in Table 1, China's emissions already exceed those of the United States; India's those of Japan. If deforestation is included, as it should be, Indonesia is the third largest emitting country, followed by Brazil and Russia. The problem of global climate change simply cannot be addressed without going well beyond the countries listed in Annex I of the 1992 Framework Convention on Climate Change.

It is also desirable, insofar as practicable, to cover all the significant greenhouse gases. Six types are listed in the Kyoto Protocol, of which carbon dioxide is the weakest. Methane, nitrous oxide, some fluorocarbons, and several other gases are much more potent at the molecular level, although much less abundant and less durable. In the United States, for instance, carbon dioxide accounted for only 84 percent of the radiative forcing in 2006 (in CO_2 equivalents calculated over 100 years, EIA, 2008). Wider coverage implies a lower charge for any given reduction, and it is likely to be easier to reduce some non-CO_2 sources of warming faster than CO_2 in the short run. Practical difficulties arise in levying a charge on methane produced in agriculture. This accounted for only 2.5 percent of radiative forcing in the United States, but the share is probably higher in many developing countries, especially those that grow rice. Thus coverage might exclude the entire agricultural sector (except for marketable energy consumed in agriculture), which also accounts for the bulk of nitrous oxide; or it might reach nitrous oxide through charges on the relevant fertilizers, and exclude only agricultural methane.

Deforestation accounts for a significant, although not precisely known, emission of carbon dioxide. Forestry should be included, both because of the magnitudes involved and because to exclude it would encourage arbitrage around the carbon charge, for example by clearing natural forests to plant materials (e.g. oil palms) for biofuels. Certain practical difficulties arise, both in estimating the emissions – although satellite observations make this increasingly possible -- and in identifying exactly where the charge should be levied (taken up below).

An initial charge would be set by international agreement. It should be high enough to affect behavior significantly, but not so high as to lead to unwarranted adjustments. I suggest $15 a ton of carbon dioxide equivalent ("carbon" hereafter will be used to cover charges on other greenhouse gases at their carbon-dioxide equivalent in terms of radiative forcing over 100 years).[2] In the United States this would add about 1.78 cents per kilowatt-hour to the busbar cost of coal-generated electricity, and 13 cents to a gallon of gasoline, before allowing for indirect costs, e.g. for distribution (Metcalf, 2007, p.15).

The charge should be subject to periodic review. An expectation might be that the charge would rise over time, as shown in the optimal scenario by Nordhaus (2008) and in various scenarios by Edmonds et al. (2008). But there is much uncertainty about the future – regarding the influence of carbon emissions on climate, regarding the trajectory of carbon emissions, regarding the influence of the charge on carbon emissions, and regarding new technological developments with regard, inter alia, to the development of economical non-carbon sources of energy. As time goes on, we will learn more about the nature and extent of climate change, about its impacts, and about new technological possibilities. We will also learn how responsive firms and households are to the carbon charge. The charge might initially be set for ten years, and then reviewed and adjusted up, or possibly down, at five-year intervals thereafter.

Compliance would be easy to assess. The International Monetary Fund (IMF) has a fiscal division that is well-informed about the tax systems of all member countries (which include all important economies in the world; Taiwan, Hong Kong, Cuba, and North Korea

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[2] This works out at $55 a ton of carbon, the unit of measurement used by the IPCC and some other analysts. Readers in this field need to pay attention to the units used.

are the significant exceptions). The IMF could be tasked with reporting whether adherents to the carbon charge agreement had in fact passed the required legislation and set up the appropriate administrative machinery. This would be an assignment for the regular Article IV consultations which the IMF holds with all member countries.

The obvious place to levy the charge from an administrative perspective would be the upstream choke points: refinery input for oil (plus bunker fuel and a few other places where crude oil is used directly); major pipeline collection points for gas; and mineheads or rail and barge collection points for coal. The charge would also be levied on imports of fossil fuels, and would not be levied on exports (e.g., Canada would levy a charge on fossil fuels consumed domestically, but not on exports of gas to the United States; the United States would levy the charge on its imports of gas from Canada). An alternative, fallback would be to levy the charge at power plants and other large direct emitters of CO_2, such as cement plants and steel makers. In general, the charge would be passed into downstream prices. But this is an issue of administration, and discretion would be left to each country, provided the agreed objective was met.

Would countries, especially poor countries, be able to administer a charge on carbon emissions? This should be possible for all but the poorest and least competent countries, for they do raise significant revenue now, typically ten to 25 percent of GDP, and they have a demonstrated capacity to levy duties on imports of goods, which also go through chokepoints such as sea- and airports. Administratively incompetent countries are also low emitters.

An issue would arise with respect to pre-existing charges or taxes (or, in some cases, subsidies) on energy. The internationally-agreed charge would go on top of those, without allowance for them. The argument is that their rationale, whatever it may have been, pre-dated international concern with climate change. Climate change is a new, global concern, requiring a global solution. Thus all countries should contribute to mitigating it after identification of the concern and agreement on the action. An exception to this "grandfathering" of pre-existing taxes might be made for those (few) countries that imposed energy taxes in response to their obligations under the Kyoto Protocol, i.e. during the past decade, or perhaps in anticipation of Kyoto. Presumably the few actions taken at the subnational level, e.g. by British Columbia, will be integrated into national systems under the proposal.

Imposing the charge on deforestation would be more difficult, but surrogates could be found. For example, estimates could be made of the waste wood, and carbon emissions therefrom, associated with timber of various kinds, and an appropriate levy could be made on the timber in the country of origin or, if appropriate, by the importing countries. Forest clearing for commercial ranching would also be covered. Slash and burn agriculture in very poor societies, where property rights are ill-defined, would be much more difficult, but that accounts for only a small portion of emissions arising from changes in land use, and over time the abandoned fields usually revert to heavy vegetative cover.

Taking the required legislative and regulatory steps and actually collecting the charge are two quite different things. The IMF could be asked to estimate the revenues that should be collected by each signatory country and assess whether they are in fact being collected. Satellite observation of power plants and other large sources of heat, and of deforestation, along with data on imports of crude oil and petroleum products, coal, and gas could help in estimation of carbon emissions, along with provision for occasional on-site inspection. The IMF reviews could assess whether significant revenues are being collected, since it routinely reviews government revenues, expenditures, and changes in public debt.

There is some risk that countries could impose the carbon charge, but then weaken its effects through changes in other taxes and/or subsidies to the industries or consumers most affected. Again, careful monitoring of the entire tax/expenditure system of each country by the IMF could identify and expose the worst abuses. But another point needs to be made: so long as the charge is systematically imposed on carbon emissions, firms and households would have an incentive, at the margin, to reduce carbon-emitting activities, even if their total burden were mitigated by other tax breaks (which might, for example, keep some firms in business that would otherwise shut down).

If a country were found to be out of compliance, it could be asked in informal consultations, and ultimately in formal international panel reviews, to explain its position. Systematic cheating could of course be possible on a small scale. It would be more difficult on a large scale, and would have to involve the complicity of many officials, something that is increasingly difficult in the age of the internet and whistle-blowers.

If a country were significantly and persistently out of compliance, its exports could be subject to countervailing duties in importing countries. The conceptual and legal basis for such duties – to offset government subsidies to exports – has existed for many years, and is embodied in the World Trade Organization as well as in national legislation. The new element is that under the international agreement the agreed charge on carbon emissions would be considered a cost of doing business, such that failure to pay the charge with government complicity would be considered a subsidy, subject to countervailing duty under existing procedures.

Non-signatory countries could also be subject to countervailing duties. WTO panels have found that imports can be restricted on a discriminatory basis if the originating country is in violation of an international environmental agreement (Webster, 2008; Frankel, 2008). This possibility would provide a potent incentive for most countries to comply with the agreement, whether or not they were formal signatories.

Suitable credits would be given for activities that withdraw carbon dioxide from the atmosphere. The most obvious ones concern reforestation, e.g. of forests that are harvested for paper pulp or other commercial purposes; and carbon capture and sequestration (CCS), which may in the future become an important technique for preventing carbon emissions from entering the atmosphere, particularly at coal-fired power plants.

Economic Effects

The imposition of a charge on a sector of the economy as significant as energy will have many potential effects on each economy. Of course the purpose of the charge is to reduce greenhouse gas emissions. In addition, the charge will affect revenues, may have macroeconomic and inflationary effects, may affect growth, and will have potential impacts on both the domestic and the international distributions of income.

Emission Reductions How much will a charge of $15 a ton of CO_2 (or any other particular charge) reduce greenhouse gas emissions? The honest answer is we do not know. But we have both evidence drawn from work on energy and simulations regarding energy charges that suggest that the short run response will be relatively low – energy consumption is deeply embedded in modern economies, and not easily changed – but that the long run response will be much larger. A carbon charge will affect emissions through three identifiable channels. First, households can be expected to reduce their spending on energy directly, and on energy-intensive products, both of which will be more expensive after imposition of the charge. Less electricity (than otherwise) will be consumed, less gas or oil for heating, less motor fuel. More insulation will be installed. Consumers will pay more attention to the life-time costs of appliances, automobiles, apartments and other long-term purchases as they become conscious of the higher energy costs, and shift their purchases to products with lower energy usage.

Second, firms will respond by producing goods that are more energy efficient, and they will alter their production techniques to use less energy – a process that was observed extensively in Europe, Japan, and the United States following the sharp increase in oil prices in the mid-1970s. Developers will use more energy-efficient building materials, will install more insulation, and will orient their buildings to minimize the impact on users of cold winter winds and maximize the impact of winter solar heating in northern latitudes, while maximizing the use of breezes and minimize solar heating in tropical latitudes. Many of these adaptations will involve substituting capital for energy.

Third, low carbon-emitting fuels will where possible be substituted for high-emitting fuels in energy-using processes, e.g. wind, hydro, nuclear or gas for coal and oil in electricity generation.

How sensitive is demand to price? In one 1990s survey of studies of energy demand, a mean long-run price elasticity of -0.5 was found; that is, a ten percent increase in energy prices would reduce demand for energy by five percent (Atkinson and Manning, 1995). Cooper (2003) estimated a comparable long-run demand elasticity for crude oil. Simulations by the Emissions Predictions and Policy Analysis (EPPA) model at MIT suggest that the rate of GHG emissions would drop by 14 percent in the first five years following introduction of a $15 a ton charge in the United States (reported in Metcalf, 2007, p.12), although CO_2 emissions alone dropped only 8 percent in the first five years.

Simulations run on DOE's Pacific Northwest National Laboratory model MiniCAM suggest a global drop from its reference projection by 14 percent in CO_2 emissions from fuel and industrial sources by 2020 following introduction of a CO_2 emissions charge of $15 a ton in 2012, and a drop by 30 percent if land-use sources of CO_2 are also effectively covered by the charge. (Land-use sources accounted for 13 percent of global CO_2 emissions in the base year 2005, but become strongly negative – due to reforestation? – following introduction of the carbon charge.)[3]

Not surprisingly, the reductions under a common carbon charge differ from country to country, reflecting differences in cost associated with reductions in emissions, which in turn reflect in part the different initial levels of efficiency with which energy is used, as well as the different opportunities provided by growth to install less carbon-intensive processes. Thus the industrialized countries generally show lower percentage reductions – 9.3 percent for the USA, near the EPPA estimate of 8 percent, 11.8 percent for Europe and Japan – than do emerging markets. China, of special interest since by 2020 its CO_2 emissions are nearly twice those of the United States in the reference projection, shows a reduction of 18 percent, while in India industrial and fuel emissions fall by 17 percent relative to the baseline.

Ho and Jorgenson (2007) examine the impact of fuel taxes in China for the purpose of reducing health-damaging pollution. Their analysis is applicable to CO_2 emissions. They produce a multi-sectoral model of the Chinese economy, with exogenous technical change and savings rates, calibrated to Chinese data for 1997. They then notionally impose fuel taxes of 40 percent of the estimated damage to health from pollutants caused by burning coal and oil. The result is a 24 percent tax on coal and about one percent on oil, which in their simulation results in a decline (relative to a baseline projection) in coal use by 16.8 percent and in CO_2 emissions of 13.6 percent. The results show a high long-term response to an implicit low charge of $1.72 per ton of CO_2 emission from consumption of coal; some of this high response is due to the substitution of untaxed gas for coal, but also to their assumption of a high long-run substitutability of capital for energy. Higher charges would reduce emissions further, but at a declining rate. An important qualification is that technical

[3] I am grateful to Jae Edmonds for running these simulations. See also Edmonds et al., 2008.

change in the model is assumed to be exogenous, not responsive to price incentives, surely contrary to reality at the global level if not in China.

An important finding of the Ho-Jorgenson work -- indeed its main focus – is that reduced consumption of coal in China would have very significant health benefits as well as contributing to mitigation of climate change.

Revenues These various studies suggest that both in the USA and in China demand would respond significantly to a carbon charge. But the response would not be overwhelming at the charge suggested, and much carbon dioxide would continue to be emitted. Thus the charge would produce significant revenue. To avoid a significant contractionary macroeconomic effect, the revenue would need to be recycled into the income stream, either through increased government expenditures or through a reduction in taxes. Ho and Jorgenson, for instance, assume that the revenue collected in China is used to reduce taxes on commodities, labor, and capital in a way that is revenue neutral. Under the proposal, each country would retain the revenues it collected from the carbon charge, and could use it in any combination of additional expenditure or tax reduction that it chose, provided the choice did not undermine the purpose of the charge, which is to reduce carbon emissions. The macroeconomic impact of the carbon charge could also be kept low by introducing the charge gradually, at a pace consonant with the increased expenditures or reductions in other taxes.

The introduction of the charge would raise the price of fossil fuels – indeed, that is its principal purpose – and of energy-intensive goods and services. It is important that the charge not be undermined by a general rise in inflation. By itself, the charge would raise the price level of the consumer price index in proportion to the weight of fossil fuels, direct and indirect, in the consumer price index. The monetary authorities would need to assure that this rise did not get translated into an inflationary process, whereby workers and capitalists attempted to recoup the loss through higher wages or higher returns. Public discussion of the issues involved, plus a firm hand at the central bank, should contain this potential problem. Use of revenue at least in part for tax reductions would also help in this endeavor.

The revenues produced by a carbon charge would be substantial, but not overwhelming. If we apply the $15 per ton of CO_2 charge to world emissions in 2015, as projected by the US Department of Energy, and assume no behavior response at that time, world revenues would come to $515 billion, or about 0.7 percent of gross world product in that year. Table 2 shows the revenues, and revenue as a share of projected GDP, for the USA, Europe, Japan, China, and India, again on the assumption of no behavioral response in that year (as might be the case if the charge were first introduced in that year, with inadequate advance notice). For the rich countries, revenue is generated in the tens of billion dollars, but less than half a percent of GDP, and perhaps one percent of revenue for the USA and Europe, less for Japan. For China and India revenue is over one percent of GDP, and perhaps over five percent of revenue in 2015, augmenting significantly the choices those governments could make. Behavioral responses to reduce carbon emissions – the objective of the charge – would of course reduce these revenues, by amounts that depend on the magnitude of the response. Metcalf's report on the MIT simulation, noted above, suggests that in the short run a $15 charge in the United States would reduce that country's CO_2 emissions in the short run by 8.4 percent; applied to the data above for 2015, US carbon charge revenues would decline from $93.4 billion to $85.6 billion.

Table 2
Estimated Revenues from Carbon Charge
in 2015, before Behavioral Response

	CO2 Emissions (billion metric tons	Revenues ($bn)	Revenues/GDP (percent)
World	34.3	515	0.7
USA	6.2	93	0.4
Europe	4.7	70	0.4
Japan	1.2	18	0.2
China	8.2	104	1.3
India	1.6	24	1.1

Note: assumes GDP price increases of 3 percent a year between 2000 and 2015, plus a twenty percent appreciation of the Chinese yuan against the US dollar.

Source of underlying data: EIA, International Energy Outlook, 2008.

Allowing for behavioral response would reduce worldwide revenues by 14 percent in the PNNL model, US revenues by nine percent, and China's revenues (relative to a much higher baseline) by 18 percent.

Gradual reduction of carbon emissions would of course reduce the revenue base over time. Whether revenues rose or declined would also depend on the level of the carbon charge. In any case, significant revenues are likely to be available for several decades, although not forever. In the PNNL model fuel and industrial emissions decline by 20 percent relative to baseline by 2050, but total global emissions continue to rise, suggesting a need (in that model) to raise the carbon charge for several decades.

Growth Effects Some will be concerned that raising prices on energy will discourage economic growth, especially in developing countries, since energy is a critical input to all modern economies. The impact of a carbon charge on long-term growth is likely to be negligible, at least with the right complementary policies, and may even be positive. The issue can be discussed under four headings: energy as a direct input to production; use of the revenue from the carbon charge; impact on the cost of capital and hence potentially on the rate of investment; and impact on international competitiveness and hence potentially on export growth.

Energy is a key input to many aspects of modern economies, including traditional activities such as agriculture. Surely raising the price of energy will discourage production? Recall, however, that for a variety of reasons energy is used very inefficiently in China, India, and indeed many developing countries, relative to actual practice in rich countries. Thus the possibility exists to produce the same output with a lower input of energy. Sometimes this change simply requires an adequate incentive, such as higher energy prices. Sometimes it requires an incentive plus new knowledge about better practice. Sometimes it requires an incentive plus new investment in more energy-efficient structures or equipment. And of course new investment requires funding. So investments may be diverted from other destinations to energy saving, and on that account lower growth. It is noteworthy, however, that many energy-saving investments would yield handsome rates of return if energy prices were higher. Moreover, developing countries must make large investments in power generation and distribution to support their growth aspirations, and to the extent energy efficiency can be improved, such investment could be reduced, releasing both labor and capital to be used elsewhere in the economy, thus contributing to growth. On one estimate, for example, China must spend an average of $67 billion a year over the period 2001-2030, over two percent of GDP, to satisfy its growing requirements for electricity (IEA, 2003, p.353). Even saving ten percent of this would leave $7 billion a year for investment in other activities.

As noted above, a carbon charge will raise revenue. How those revenues are used can influence the rate of growth. If they are used to replace growth-inhibiting taxes on capital, the net impact might be to accelerate growth. Thus the simulations by Ho and Jorgenson (2007, p.357) find that GDP is actually higher with a carbon charge, revenues used to reduce other taxes, than it would be without the charge – i.e., growth has been (modestly) stimulated by the charge.

If, as is more likely in many developing countries, the revenues are used to finance expenditures, the impact on growth will depend on the magnitude and the growth-enhancing effects of those expenditures. Expenditures on transport infrastructure will presumably contribute to growth, as would expenditures on under-funded agricultural research and dissemination, or on education. Expenditures on enlarging or modernizing military forces, in contrast, would not contribute much to growth. Thus each government would have substantial discretion over how much the carbon charge could be directed toward enhancement of growth. Certainly the revenues can be better used for growth than for subsidizing fossil fuel consumption, as is now done in many countries.

A third channel of influence on growth would be through the cost of capital goods, hence the real investment that could be undertaken for any given nominal level of investment spending. Raising the cost of capital goods, other things equal, will reduce growth. Raising the price of energy would increase the cost of those capital goods that are high in direct energy content, such as construction steel and cement. On the other hand, many capital goods are not energy intensive. Moreover, the impact of energy price increases on capital goods prices would be mitigated to the extent, per the first point above, that as a result of the carbon charge producers increase significantly the efficiency with which they use energy. It is even conceivable that capital goods prices would fall, as efficiency improvements outweighed increased energy prices. Furthermore, in a sufficiently long run technical change can be expected, as in the past, to reduce the prices of many capital goods. There has been no secular decline over recent decades in the real return to capital in rich countries, those on the technological frontier, as capital-saving technical change has compensated on average for the declining returns that might have been expected to flow from the tremendous accumulation of capital that has occurred during the past half century.

Finally, higher energy prices, other things being equal, will increase the relative price of energy-intensive products, hence reduce the competitiveness of those products on world markets. A serious loss of competitiveness could, through a variety of channels, reduce economic growth.

Here the international environment in which any country imposes a carbon charge comes into play. Under the proposal here, all countries would impose a similar carbon charge, so the competitiveness channel would be neutralized for all countries. Energy-intensive products would see a rise in relative price everywhere, so their consumption would be discouraged, and countries that specialized in the export of such products would experience an impact on their exports. But no country would gain directly in competitiveness product-by-product at the expense of other countries, except insofar as they were superior at reducing the energy content of their exports, or at substituting other energy sources for carbon-emitting sources of energy.

A charge on carbon emissions can be expected, over time, to stimulate new research and development on methods to reduce the carbon content of energy. It is difficult to predict the development and impact of future technology, but in the end this could provide a significant positive impetus to growth.

Distributional Effects Introduction of a carbon charge will have distributional effects across members of each country's population, and between countries. The revenues from the charge, which under the proposal will accrue to each country levying it, can if desired be used to compensate the serious losers from introduction of the charge in whole or in part. Within countries, distributional effects will occur across sectors of the economy, with carbon-intensive sectors experiencing the main decline in demand (which is the point of the charge); but distributional effects may also occur across income classes, insofar as the carbon-intensity of consumption differs significantly across income classes.

Based on a simulation by MIT's EPPA Model keyed to a carbon charge of $15 a ton of CO_2 in the United States, Metcalf (2007) reports a short-run (i.e. within the first five years after imposition of the charge) declines in demand for coal of 14.7 percent, in demand for petroleum of 5.6 percent, and in demand for natural gas of 3.4 percent. These differing percentages respond to the differing price changes caused by the common carbon charge, which in turn reflect the differing carbon intensities per useful energy of the three fossil fuels. Both petroleum and gas are imported, so some of the burden of the tax may be absorbed by the foreign exporter and show up as an improved terms of trade for the United States. This possible effect, which might mitigate the impact on output (although not profits) of domestic producers is not reflected in the estimates above. Clearly the main burden would fall on coal miners and on the owners of coal mines. A similar result is likely in many other countries. The economic impact on miners and perhaps mine owners could be mitigated through transitional compensation.

Table 3

Changes in Household Disposable Income
(percent)

Income Decile	Carbon Tax	With Income Tax Credit to Workers[a]	With Tax Credit to Workers and Social Security Recipients[b]
1	-3.4	-0.7	1.4
2	-3.1	-1.0	1.0
3	-2.4	-0.2	0.6
4	-2.0	0.1	0.3
5	-1.8	0.1	0.1
6	-1.5	0.3	0.1
7	-1.4	0.2	0.1
8	-1.2	0.2	-0.1
9	-1.1	0.0	-0.1
10	-0.8	0.0	-0.2

[a] of $560
[b] of $420

Source: Metcalf (2007), pp. 17-18.

There may also be distributional effects by income class. Metcalf (2007) has calculated how a $15 charge would affect retail prices, and how these prices in turn would affect the disposable income of different income classes in the United States, by income decile. As can be seen in the first column of Table 3, these effects are mildly regressive, hitting the low-income first decile hardest and the high-income tenth decile the least. Metcalf calculates that the regressivity can be reduced by giving flat income tax rebates to all workers, the results of which are shown in the second column of Table 3. On the basis of revenues calculated to be available, the per worker rebate comes to $560. Some negative impact continues to fall on the low-income deciles, many of whose members are retirees, thus not eligible for a rebate to workers. By extending the rebate to recipients of social security (the American public pension system), the rebate falls to $420 but the combination of carbon charge and rebate is made mildly progressive, as shown in the third column of Table 3.

The generic point is that distributional effects will arise following the imposition of the charge, but that the revenues that the charge generates provides the wherewithal to compensate serious losers in whole or in part if the government chooses to do so.

Unlike some other proposals, the proposal here does not provide for direct transfers among countries. I believe this is a desirable feature of the proposal, since the history of unconditional transfers among countries (except the Marshall Plan), or even many conditional transfers, is not a happy one. But there will still be some distributional effects among countries because of the sectoral effects noted above. Exporters of coal, in particular, and to a lesser extent exporters of oil and of gas, will experience a decline in demand for their products (although due to substitution possibilities of gas for coal in electricity generation, the global demand for gas could conceivably rise), and consequentially some decline in the prices they receive. The terms of international trade will turn against them. By the same token, changes in the terms of trade will benefit net importers of these products. The countries that stand to lose most from a decline in global demand for coal are the big exporters of coal: South Africa, Australia, the United States, and Colombia. The first three, as importers of oil, will be partially compensated by a decline in oil prices; but that will hit Colombia, as well as the many other net exporters of oil. Countries such as Japan and Korea will be beneficiaries of these price changes. Similar changes in the terms of trade, it should be noted, would also occur under an effective global CAT system, or indeed under any effective scheme. In recent years, of course, exporters of all fossil fuels have experienced a dramatic increase in the prices they receive, and a $15 a ton carbon dioxide charge will still leave them with much higher prices than they enjoyed in the early 2000s.

Two Further Potential Objections

Uncertainty One objection raised against the proposal of an emissions charge is that the resulting reductions in emissions will be uncertain, since before we try it we do not know how extensive the response in reducing emissions will be. That is entirely true. The whole domain of climate change and policy toward it is replete with uncertainty. As Nordhaus (2008) has pointed out, the presence of uncertainty does not always lead rationally to more stringent action or to quantitative restrictions. We need to learn by doing as well as by continuing research on the earth's climate and its impacts. Long-term forecasts of energy consumption have been notoriously poor (Abt, 2002; Smil, 2003). Levying a specific carbon charge is only a first step, with the second and subsequent steps much clearer and more straightforward than under a Kyoto-type agreement with seriously incomplete coverage.

One thing we do know, and can guess at the response to it. Under quantitative caps the variability of the price of tradable emission permits is likely to be high. Prices will absorb all the adjustment required by shocks of various kinds, for example a sequence of unusually cold winters. Unexpectedly high prices will be costly to economic activity, as some plants may have to shut down because they cannot pay the high prices. This in turn will evoke appeals for relief, which governments may (sensibly) provide. But that prospect undermines the apparent quantitative certainty of the caps.

There is a deeper philosophical issue here. A tight and effective cap implicitly places prevention of CO_2 emissions above all other social objectives, insofar as it in principle requires society to pay any cost to stay within the quantitative target. That feature may recommend caps to some observers. But well-ordered societies do not generally attach infinite economic value to any single objective. Just as individuals usually trade off one objective against another, depending on the incremental costs and benefits of each, so do societies. Democratic societies do so through open public debate and political compromise. If some important objectives are threatened, they are likely to be saved by easing up on other objectives.

Equity A second objection to the proposal is that it deals inadequately with "equity." Increased CO_2 concentration in the atmosphere is due in considerable measure to emissions by today's rich countries during the course of their development over the past two centuries. Therefore, some observers argue, today's rich countries should bear the burden of reducing CO2 emissions and, eventually, atmospheric concentration. This concept of equity is highly dubious. What looks "equitable" to one person looks highly inequitable to another. When Englishmen launched the coal-based industrial revolution, they had no idea that climate change three centuries later would be a consequence. Why should their descendants be held responsible? When Americans in the mid-19th century created the petroleum industry with the invention of kerosene (a substitute for increasingly scarce whale oil), they did not know its full long-term implications (including, probably, saving several species of whales from extinction). Moreover, on one estimate the rich countries are not overwhelmingly responsible for the increased concentration of greenhouse gases in the atmosphere. If changes in land use are taken into account, the rich countries account for only 55 percent of the increase since 1890, the poor countries for 45 percent (Mueller et al, 2007). A debate over past culpability will not help solve a global problem. Economists teach that optimal decisions generally require by-gones to be ignored: in this as in many areas we should look forward rather than backward, and provide adequate incentives for desired behavior. To focus on alleged retrospective wrongs of the remote past is to assure inaction.

Another reason advanced for having rich countries bear the exclusive or at least the major burden of cutting GHG emissions is that they can afford it. "Ability to pay" is a hallowed principle of public finance. But so is the principle that he who benefits should pay the costs. It is widely claimed (which does not make it correct) that the main burdens of climate change will fall on peoples living in the tropics, i.e., mainly people who today are poor, while some living at higher latitudes may actually gain, at least for decades, from climate change (see, e.g., Mendelsohn et al, 2006). If this is correct, the tropical countries ought to be those most interested in reducing greenhouse gas emissions, and to be willing to pay at least their share, and perhaps more.

I conclude that the only equity argument with enduring merit is that everyone who emits greenhouse gases from now on should be discouraged from doing so, insofar as practicable, in proportion to their emissions. The rich will and of course should pay more because they emit more per head.

We now believe that continued greenhouse gas emissions will damage our descendants, albeit unevenly. Such emissions have a social cost that is not reflected in the current prices of coal, oil, and other sources of greenhouse gases. A charge should be added to the prices we would otherwise pay. All emitters, rich or poor, should pay the charge. An analogy would be with all current users of copper or other natural materials. All users pay the full current price of copper, regardless of their level of income, and regardless of who consumed copper in the past. We need to think of GHG emissions as a scarce resource, like copper, that needs to be rationed by all who use it.

Energy Security

Energy security is a common political theme these days. But achieving energy security and mitigating climate change are only coincidental policy bedfellows. Conservation of energy serves both objectives. But energy security really concerns oil and gas (the latter especially for Europe, although a growing number of countries will become dependent on imported gas), while at its heart mitigation of climate change concerns coal, even while oil plays an important supporting role. Serious mitigation of climate change might even increase dependence on gas, as a lower-emitting fuel for electricity generation. Substitution of electricity and eventually hydrogen for petrol in automobiles and trucks will improve energy security, but they would put more pressure on the climate insofar as coal and gas are used to generate the electricity. Similarly, coal liquefaction would reduce demand for imported petroleum, but would be bad for the climate. To the extent that both these objectives are desirable, the strong emphasis needs to be on energy conservation and electricity generation with sources of energy other than coal and gas.

Mixed Systems

This paper has proposed an internationally agreed charge on carbon emissions that in principle all countries would levy. But several economies, most notably the European Union, have embarked on a cap-and-trade system. The current Australian government also seems committed to such a system, and several bills before the US Congress call for introducing a CAT system into the United States. It is worth asking, therefore, whether the two systems can co-exist. The answer is affirmative, provided several conditions are met.

A CAT country could, if it wished, introduce procedures whereby additional emission permits could be issued if the trading price of permits exceeded the agreed carbon charge by a significant amount for a significant period of time.[4] But it need not do so. It could retain a more restrictive arrangement if it wished. Other countries would only be

[4] McKibbon and Wilcoxen in Aldy and Stavins, 2007, proposed a system that mixes short- and long-term emission permits. The price of the short-term permits to be sold by governments on demand would by agreement be the same across participating countries. This is the equivalent of a common carbon charge, where the permit issuing governments retain the revenue, as in the proposal here. The difference is that each country would initially also distribute long-term emission permits, e.g. according to historical emissions, which would be tradable within but not between countries, and would therefore have (varying) market value. In the view of the authors, this would create a constituency for continuing the restraints on carbon emissions over time. It is also a mechanism for distributing political favors and, unless under careful control, for corruption.

concerned about the opposite case, in which the price of permits fell significantly short of the internationally agreed carbon charge. Thus some conditions would need to be met for the two systems to co-exist comfortably.

First, the trading prices under the CAT system over time should average no less than the internationally agreed carbon charge. For example, the average over ten years should be no less than the agreed carbon charge. This would give the CAT countries an opportunity to tighten their target limits appropriately in a quinquennial review should the permit trading price fall below the agreed charge during the previous five year period. Second, it might be agreed that if the permit trading price fell below the agreed charge by x percent for more than y months, trading partners could appropriately consider this an export subsidy and levy countervailing duties on their imports from the CAT countries. An x of ten percent and a y of six months might be reasonable values, but these variables could be subject to negotiation.

Third, countries could not provide rebates of carbon charges or permit prices on their exports, except exports of raw fossil fuels where the charge had been paid: coal, crude oil, and natural gas. (Frankel, 2008, has underlined the difficulties, and the dangers, of allowing widespread rebates on exports. See also Houser et al., 2008, for the difficulties in calculating the energy content of goods made in the United States.)

Finally, CAT countries could not give away emission permits to producers of goods and services, or at least producers of tradable goods and services. These could properly be considered production subsidies relative to a regime of common carbon charges. A CAT country would therefore have to auction the emission permits or, if it wanted to give the permits away, it could give them directly to households, on a per capita or some other basis, which would in turn sell them into the permit trading market. The objective would be to avoid either the appearance or the reality of competitive advantage being conferred by the operation of the permit system.

Negotiability

Would it be possible to negotiate an international agreement to impose a carbon charge? Why would countries such as China and India, or the United States for that matter, agree to it? The answer depends on how seriously they take climate change as a global problem, one that will affect negatively Chinese and Indians and Americans two or three generations from now. The projections in Table 1 suggest that any scheme to reduce carbon dioxide emissions must include the leading developing countries, soon. Because their highest priority is to maintain an acceptably high rate of economic growth, and this involves increasing reliance on electricity and motive energy, they are unlikely to agree on binding emission targets that are effective in mitigating climate change. The framework of international cooperation needs to be altered from one focused on quantitative national targets to one focused on mutually supportive actions. Since the only way to reach millions of decision-makers is through the price system, the natural (although not the only) focus on actions would be to levy a common charge on emissions of greenhouse gases, especially carbon dioxide.

The idea of imposing a charge on carbon emissions is in complete harmony with China's official energy strategy, adopted in 2002. In the words of one senior Chinese official, the strategy "will constantly improve the macro control and power market regulatory system, deepen the power system reform, and try hard to build up *an incentive mechanism for resource conservation, efficiency improvement, environmental protection*, and development promotion." (Wu Yin, Deputy Director-General of the Energy Department of the National Development and Reform Commission, 4/23/04, italics added). Creating appropriate incentive systems for efficiency and environmental protection are constantly mentioned by Chinese officials, as is the need to get the price of coal up to reflect its full social costs, including environmental costs (e.g. China Development Forum 2003, p.93). A charge on environmentally damaging emissions fits perfectly with this objective. China has already experimented with effluent charges, with some success (Wang and Wheeler, 1999). Limiting growth in the use of coal would also have significant health benefits for China (Ho and Nielson 2008), and also no doubt for other rapidly growing economies as well. An international agreement would also strengthen the position of the central authorities in China vis-à-vis the provinces and municipalities, where most of the enforcement problems arise.

Saudi Arabia, the world's leading oil producer, has indicated that it would not have a problem with a universal charge on carbon dioxide emissions, implying it would not restrict oil production to capture the revenues of a charge on carbon.

A carbon charge will generate significant revenues. Most governments need additional revenues, and a mechanism for raising revenues in an internationally acceptable way would be welcome, especially to finance ministries. As noted, the revenues could be used in various ways that would enhance growth, including financing research and development. And they could be used to help adaptation to such climate change as will occur despite efforts at mitigation.

Given aversion to taxes by many Americans, revenues from the carbon charge could be used there to reduce other taxes, to enhance investment and/or to neutralize the distributional effects of the carbon charge. Some portion might also be used to finance climate relevant research and development, such as the development of cellulose-based ethanol or carbon capture and sequestration from power plants and other large sources of emissions.

It is not necessary that all countries agree initially to the scheme. It could be launched with the major emitters, perhaps three dozen countries in all. But it must include both China and the United States, the two largest emitters of carbon dioxide. Thus any negotiable scheme must be agreeable to those two countries. Given its perceived reluctance to deal with climate change (although it remains the major source of research on the question, and on many alternative sources of energy), the United States would have to take the initiative, or respond enthusiastically if the initiative were taken by another country.

The likelihood, on the basis of current knowledge, that the major negative impacts of climate change would occur in low latitudes (even though surface temperature is expected to rise more at high latitudes) should provide many developing countries with incentive to participate in an internationally agreed scheme, provided the major emitting areas also participate, and provided that it was not seen to threaten their development.

If an agreement among a suitable number of relevant countries could be reached, non-participating countries would be encouraged to participate (in practice, even if not through formal agreement) by the possibility that their exports to participating countries would be subject to countervailing duties against their "subsidies" arising from their failure to impose a carbon charge.

References

Abt, Clark, 2002, "The Future of Energy from the Perspective of Social Science," in Richard N. Cooper and Richard Layard (eds.), What the Future Holds, Cambridge, MA: MIT Press.

Aldy, Joseph E., Eduardo Ley, and Ian Perry, 2008, "A Tax-Based Approach to Slowing Global Climate Change," Washington: Resources for the Future, processed.

Aldy, Joseph E., and Robert N. Stavins, 2007, Architectures for Agreement: Addressing Global Climate Change in the Post-Kyoto World, New York: Cambridge University Press.

Atkinson, J., and N. Manning, 1995, "A Survey of International Energy Elasticities," in B. Terry, P. Elkins, and N. Johnstone (eds.), Global Warming and Energy Demand, London: Routledge.

China Development Forum, 2003, China's National Energy Strategy and Reform: Background Papers, Beijing: Development Research Center of the State Council.

Cooper, John C.B., 2003, "Price Elasticity of Demand for Crude Oil: Estimates for 23 Countries," OPEC Review, 27(1): 1-8.

Edmonds, J., L. Clarke, J. Lurz, and M. Wise, 2008, "Stabilizing CO2 Concentrations with Incomplete International Cooperation," Climate Policy, vol. 8.

Ho, Mun S., and Dale W. Jorgenson, 2007, "Policies to Control Air Pollution Damages," in Mun S. Ho and Chris Nielsen (eds.), Clearing the Air: the Health and Economic Damages of Air Pollution in China, Cambridge, MA: MIT Press.

Frankel, Jeffrey A., 2008, "Addressing the Leakage/Competitiveness Issue in Climate Change Policy," processed.

Houser, Trevor, et al. (2008), Leveling the Carbon Playing Field: International , Competition and US Climate Policy Design, Washington, DC: Peterson Institute for International Economics.

International Energy Agency, 2003, World Energy Investment Outlook, Paris: OECD.

Mendelsohn, R., A. Dinar, and L. Williams, 2006, "The Distributional Impact of Climate Change on Rich and Poor Countries," Environment and Development Economics, 11: 158-178.

Metcalf, Gilbert E., 2007, A Proposl for a U.S. Carbon Tax Swap: An Equitable Tax Reform to Address Global Climate Change, Washington, DC: Brookings Institution.

Mueller, Benito, Niklos Hoehne, and Christian Ellerman., 2007, "Differentiating (Historic) Responsibilities for Climate Change," www.oxfordclimatepolicy.org

Nordhaus, William, 2008, A Question of Balance: Weighing the Options on Global Warming Policies, New Haven, CT: Yale University Press.

Smil, Vaclav, 2003, Energy at the Crossroads: Global Perspectives and Uncertainties Cambridge, MA: MIT Press.

US Department of Energy, Energy Information Administration (EIA), International Energy Outlook, various years, latest 2008.

Wang, Hua, and David Wheeler, 1999, "Endogenous Enforcement and Effectiveness of China's Pollution Levy System," Washington: World Bank, mss.

Webster, D.G., 2008, Adaptive Governance: the Dynamics of Atlantic Fisheries Management, Cambridge, MA: MIT Press.

Williamson, John, 2008, "Charging versus Cap-and-Trade as Techniques to Curb Climate Change," Washington, DC: Peterson Institute for International Economics, processed.