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<ct>Global environmental taxes

<au>Philippe Thalmann

<a>INTRODUCTION

Other chapters of this Handbook show that environmental taxes are very interesting instruments for environmental regulation. The question addressed in this chapter is whether they are still interesting when the environmental problem is a global one. Are they still effective and efficient? Are they feasible and acceptable? First, however, a few definitions are needed: what are global environmental problems and how could taxes help address them?

A global environmental problem is an environmental problem to which nearly all countries contribute and that affects nearly all countries of the world. This implies that nearly all countries should participate in resolving it. However, individual countries contribute in different amounts and are affected in different ways. They also face different abatement costs, or costs for reducing their share of environmental harm. This implies that national contributions toward resolving the problem should be modulated. Clearly, making sure that all countries participate and allocating abatement efforts efficiently across all countries will be key issues for global environmental problems, particularly as there exists no global authority that could force participation and impose abatement efforts on sovereign countries (Carraro 1999).

The main global environmental problems are climate change, ozone depletion and biodiversity loss.[1] The atmosphere and the oceans, with their absorptive capacity and the species they host, and even outer space with the room it offers, are common property resources of humanity. Everyone who uses such a resource reduces others' ability to use it. No one can prevent or regulate this in the absence of enforceable property rights.

Ozone depletion has been combated quite successfully through treaties banning dangerous substances. The success of this approach has been attributed to the possibility of rapidly replacing the chemicals. Similar bans on greenhouse gases are obviously much less feasible. Therefore, a more gradual approach is advocated for climate policy, one that leaves much more freedom to individual emitters about how and when they reduce their emissions of greenhouse gases and which gases they abate primarily. The international approach relies mainly on voluntary measures such as information, persuasion (see Baranzini and Thalmann 2004), technology transfer, and bilateral mitigation projects (clean development mechanism, joint implementation) that generate 'credits' to be used against some mitigation obligation or objective. The main internationally coordinated action is the European Union's Emission Trading System (EU ETS), a cap-and-trade system for large carbon dioxide emitters. In

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[1] The depletion of mineral resources could be added to this list, with some precautions. Indeed, contrary to the atmosphere and the oceans, ownership rights are often well defined for mineral resources (but not always, viz. deep ocean resources). However, their owners may overexploit them, at the expense of future generations of the world population. Their depletion at an inefficient rate is similar to the depletion of natural resources without ownership.

addition, nearly all countries have implemented some climate policy, drawing on a mix of these instruments, augmented with regulation, subsidies and taxes.

Based on the experience with domestic carbon taxes and economists' long-standing promotion of this instrument, the question of whether that potentially very effective and efficient instrument could also be used at the international level naturally arises, particularly as its environmental- and cost-effectiveness could grandly be augmented by international coordination.

Since climate policy is the area in which a global environmental tax has received the greatest attention by the political and scientific community, this chapter concentrates on the carbon tax. However, the assessment of the global carbon tax can easily be carried over to other global environmental taxes. A good part of the assessment of the global carbon tax also extends to a broader approach, that of global carbon pricing (advocated by the OECD, among others (OECD 2009, Chapter 4)), which includes reductions in subsidies to fossil fuels and a market for carbon dioxide emission certificates.

<a>THE DESIGN OF A GLOBAL CARBON TAX

Two possible formats for a global carbon tax have been discussed extensively: harmonized taxes and an international tax (Hoel 1992). In the first, a set of countries agree to raise their carbon prices. They might agree on the same tax rate or on different rates in different countries, for instance lower rates in less developed countries. The rates could be set with a quantity objective or at a level corresponding to external costs. Tax revenues accrue to each country but a part could be put into a common fund and used for international transfers.

With the international tax design, each country is taxed on its national emissions,[2] and each has to pay into a common fund an amount that is proportional to its total CO_2 emissions. At the Toronto Conference on the Changing Atmosphere of 1988, the creation of a World Atmospheric Fund was recommended. Under that proposal, the revenues are returned to the participating countries in fixed shares. Each country is free to decide how it finances its net contribution to the common fund, whether by a domestic carbon tax or by any other means.

Apart from these overarching schemes, one can imagine all sorts of combinations of national carbon taxes with other instruments that would create international links. For instance, firms could be exempted from the domestic carbon tax if they deliver foreign ETS permits for their emissions.[3] OECD (2009, 120) even envisages the reverse option, namely that a firm could avoid buying domestic ETS permits by paying the carbon tax enforced in a foreign country. In that case, the foreign carbon tax would place a lid on domestic permit prices. Alternatively, a country with an emissions-reduction target could use a domestic carbon tax to try to

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[2] Whalley and Wiggle (1991a, 1991b) estimated the effects of a variant where the carbon tax is collected on a production basis. In that case, large producers of fossil fuels such as the OPEC countries and Russia would collect the highest tax revenues or contribute most into the common fund. Absent compensating redistribution of the revenues, there is of course an enormous difference between harmonized taxes on carbon extraction and those on CO_2 emissions.

[3] Such a model is in preparation in Switzerland, where large CO_2 emitters could buy permits on the European ETS, of which Switzerland is not a member. In practice, Swiss and EU permits would become fungible, at least for Swiss firms.

meet it and could plan to buy foreign permits if the tax turned out to be too low. It could even try to sell its own permits abroad if domestic mitigation overshot the target, provided of course that other countries accepted its permits. Such mechanisms lead to some international harmonization of carbon prices and transfers of funds.

In the following sections, we will assess the two 'pure' global tax schemes: harmonized taxes and an international tax.

<a>ASSESSMENT OF THE GLOBAL CARBON TAX

The first question to ask is: what are the criteria for assessment? The standard criteria for an environmental policy instrument are its target effectiveness (does it achieve its goal, such as a desired environmental improvement or a target revenue), cost-effectiveness (does it achieve that goal at minimum resource costs), practical feasibility (legal conditions, administrative and compliance costs), fairness (is the burden fairly shared), and, finally, acceptability.

The assessment of the global carbon tax in this chapter will emphasize the international dimensions, i.e. its effectiveness in meeting a global environmental or income target, its ability to allocate efforts across countries in a manner that minimizes total costs of meeting that target, and the way it shares the burden among countries.

The assessment criteria are not independent. Participation is more likely if countries perceive an agreement to be fair. Wide participation is necessary for target- and cost-effectiveness. Feasibility constraints may reduce effectiveness.

The global carbon tax can be assessed on its own, i.e. in comparison with no international policy, or in comparison with other instruments designed to achieve the same environmental or revenue goal, such as tradable emission quotas.[4]

<a>ENVIRONMENTAL-EFFECTIVENESS AND PARTICIPATION

An incentive tax can, in theory, be designed to meet any environmental target. Its effectiveness is reduced, however, when it is set at a low rate or when important sources are exempted for political reasons (Ekins and Speck 1999). In the case of a global environmental tax, effectiveness is threatened by nonparticipation of countries that are large emitters. Consider for instance CO_2 emitted by the consumption and flaring of fossil fuels. China and the United States together account for 41 percent of world emissions of this type. Ten countries account for two thirds of world emissions (Figure 25.1). Clearly, an agreement among these ten would have the potential to lower world CO_2 emissions substantially. Note that three of them—China, India and Iran—are not in Annex I of the Kyoto Protocol, the list of countries with an emissions-reduction target. The European Union accounts for about 12 percent of world emissions.

[Insert Figure 25.1 about here]

A global environmental tax will be effective only if at least the main emitters participate, and they must participate voluntarily as there is no world authority to

[4] For comparisons between a global carbon tax and a system of tradable quotas, see for example Cooper (2000), Green, Hayward and Hassett (2007) McKibbin, Morris and Wilcoxen (2009) and Nordhaus (2007), who all conclude in favor of the tax, and Wiener (1999), who concludes in favor of quotas.

impose participation. This concerns not only current large emitters but also future ones. Jacoby, Prinn and Schmalensee (1998) argue that even if all industrialized countries listed in Annex I of the Kyoto Protocol reduced their net greenhouse gas emissions to zero by the end of this century, that would have only a small impact on the climate, due to rapid emissions growth in the developing world. Still, the lowest-income countries might be given time for economic growth before they take over mitigation objectives. Nordhaus (2006) suggests a threshold for participation of US$10,000 per capita.

Nonparticipating countries ('pollution havens') could use the resulting competitive advantage to increase their world market shares and possibly even attract some production facilities from participating countries. As a result, global emissions would decrease less than those of the participating countries, a phenomenon known as carbon leakage. There exists a sizable empirical literature on the magnitude of carbon leakage, as this argument is often advanced against unilateral climate policy (OECD 2009, Chapter 3). Reinaud (2009) shows that phase I of the EU ETS did not lead to any significant leakage, even for particularly carbon-intensive sectors exposed to international competition, contrary to the pessimistic forecasts of simulation studies. However, the author acknowledges that the generous distribution of emission certificates did not impose much of a burden and that it might be too early to draw conclusions. Nevertheless, this confirms the results of earlier studies that showed that environmental regulation was not as important a determinant of the location of production as labor costs, taxes, or exchange rate and political risks (Cropper and Oates 1992; OECD 1993). Even so, the European Commission drafted a controversial list of sectors exposed to serious risk of carbon leakage under full auctioning of ETS permits that includes nearly one half of all sectors, accounting for three quarters of greenhouse gas emissions covered by the EU ETS.

Gaining a competitive advantage by not participating versus running the risk of losing market share by participating are strong incentives for free-riding. Hence the call for accompanying measures, mainly in the form of border adjustments: a country that imposes the carbon tax would reimburse it to its exporters and charge it on imports from nonparticipating countries. Obviously, measuring the contents of untaxed carbon in each imported product would be extremely difficult, but the number of carbon-intensive goods is not that large, so limiting the adjustments to these goods would yield a feasible and satisfactory solution (Goulder 1992). This measure, however, looks very similar to protectionist measures that are banned by WTO rules, which suggests that it must be drafted very carefully (Holzer 2010). Another solution is to start with a non-uniform domestic tax that imposes a higher rate on goods subject to less international competition (Hoel 1996).

Carbon leakage is not the only deterrent against participation in a global carbon tax scheme. Each country also weighs the burden the tax represents against the expected benefits. When the revenues of the tax are recycled in the country, its burden is equal, as a first approximation, to abatement costs. It is less, in fact, due to the ancillary domestic benefits of carbon mitigation (such as less damage due to air pollution, and terms-of-trade gains on fossil fuels imports), and even less if the revenues are well recycled ('second dividend'). Still, there could remain a net burden of the carbon tax, which might or might not be offset by the expected benefits of climate change mitigation. Indeed, countries will be affected quite differently by climate change. Some might even gain, although this is increasingly doubted. Still, some countries might make this argument in order to stay out of conjoint abatement efforts.

Even if environmental benefits exceed total net burdens in the world aggregate when the mitigation target is well set (Stern 2007), that may not be the case for each individual country. It is generally admitted that participation in a global carbon tax scheme, and in efficient global climate mitigation as a general matter, would be particularly burdensome for developing countries. OECD (2009, 59) attributes this to the 'higher carbon-intensity of their economies.' On the other hand, developing countries are also expected to gain the most from avoided climate change because of their greater exposure. Nevertheless, with their great difficulties in addressing the current needs of their populations, developing countries generally attach less priority to preserving the environment and discount the future at much higher rates than developed countries do, which is understandable if they expect stronger consumption growth rates than the latter (Dasgupta, Mäler and Barrett 1999). For both reasons the balance of carbon abatement costs and benefits is strongly tilted toward the costs side.

The fact that total abatement costs will be inferior to the cost of no action when the target is appropriately set implies that climate mitigation generates a global 'surplus' potentially sufficient to compensate countries for which abatement costs exceed benefits. This potential compensation may well have to become real to make at least all major emitters participate. The UNFCC (Article 11) provides for such a financial mechanism, which is operated by the Global Environment Facility (GEF) created in 1990. Remember, however, that the benefits from mitigation will accrue in the distant future in the form of avoided damages, not an easy source of funds for compensatory payments today! Alternatively, the global carbon tax might be part of a wider international environmental agreement, which might provide for different forms of conditional side-payments, technology transfer, trade sanctions and so forth (for a survey, see Wagner 2001).

If redistribution of funds is a condition for participation, some of the revenues of the harmonized national taxes would have to be put into a common pool. The international tax would automatically direct huge revenues into the common pool if the tax is designed to induce significant mitigation. Most of those revenues would be contributed by the richer countries. It is, however, doubtful that these countries would participate and entrust huge funds to an international body.[5] Neither is it clear that their electorates would support large payments to countries where they might raise governance issues (OECD 2009, 59).

These concerns could be addressed by imposing the international tax above some national quota of tax-free emissions, i.e. participating countries would pay only the tax on emissions exceeding their quota. If the quota were too generous, exceeding the level of emissions the country would choose in the face of the tax, the tax would be entirely ineffective. It would be effective if it could turn into a subsidy for countries that emitted less than their quota. This is illustrated in Figure 25.2. The high-income country optimally decides to abate the amount A* of its CO_2 emissions under the tax, because beyond A* the marginal cost of the additional abated ton would cost more than paying the tax. Therefore, its residual emissions are equal to E^0 A*, E^0 being total emissions without any abatement, or the maximum abatement volume. With a regular carbon tax, this country would have to pay an amount equal to the surface of the rectangle of which one side is the segment E^0 A* and the other is

[5] Schelling (1991, 215) had estimated the contribution of the United States at some US$100 billion per year, a figure that is confirmed below.

equal to the tax rate. With a quota of free emissions E^f, the country effectively only pays the tax on its excess emissions, or E^0 E^f A^*. The amount of that tax corresponds to the darkened rectangle. With the same reasoning, the low-income country, which emits little and has low marginal abatement costs and a generous quota, chooses residual emissions below its quota. It is rewarded by the amount represented by the darkened rectangle. Under this scheme, both high- and low-income countries have the same incentive for mitigation: the amount that the former pays into the common fund are limited, and the latter is clearly rewarded for its efforts by an amount that covers a good part of its abatement costs (the surface under the MAC curve).

[Insert Figure 25.2 about here]

In spite of its attractive features, this solution does not simplify the negotiation process. It is still necessary to agree on the tax-free quota for each participating country. On the other hand, the international tax design leaves each nation its sovereignty over how it finances its contribution to the common fund, infringing much less on the delicate matter of tax systems than does the harmonized tax scheme.[6]

<a>REVENUE-EFFECTIVENESS

That its revenues can be used for compensation payments is of course the attractive feature of a global tax, compared to tradable quotas allocated for free. The amounts involved are potentially huge. Not surprisingly, some have proposed to reverse the perspective: to raise a global environmental tax for its revenue potential, the

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[6] Loss of tax sovereignty was the killer argument against the European project of a centralized mixed carbon and energy tax, particularly as unanimity was required for its adoption (Zhang and Baranzini 2004).

environmental improvement being the welcome side-effect. A revenue target would be set and the effectiveness of a global environmental tax in meeting this target would take the place of environmental-effectiveness as the main purpose. This would have the practical implication that the tax rate would be set not to attain a mitigation target or to internalize external costs but to raise a desired amount of revenue.

Many different revenue targets have been proposed for global environmental taxes, with corresponding hypothecation of the tax revenues. Earmarking of revenues is fundamentally a constraint on spending that ought to be avoided, but it is often necessary in order to make a tax acceptable. This seems to be particularly the case for global environmental taxes. The international community seems more likely to accept such taxes if their revenues are earmarked for international spending, especially spending related to the nature of the taxes. Such earmarking of the revenues may also be needed when the main purpose of the global tax remains environmental-effectiveness.

Thus, it has been proposed to dedicate the revenues of carbon taxation to international development funding (Atkinson 2004), with the argument that climate change threatens the economic growth of the poorest countries, both through the burdens of mitigation and adaptation and the remaining impacts of climate change (Sandmo 2004). The World Bank estimates annual mitigation costs in developing countries between US$140 billion and $175 billion by 2030, but since this requires mostly up-front investments, the financing needs in the early years are two to three times larger. To that must be added some US$30 billion to $100 billion every year for adaptation, which would not avoid all damages (World Bank 2010, 259–60). In the Copenhagen Accord and reinforced at the 16th Conference of Parties in Cancun in December 2010, the developed countries committed to mobilizing jointly US$100 billion per year by 2020 for mitigation and adaptation actions in developing countries. A 'Green Climate Fund' is to be created, but there is no agreement yet on how the money would be raised. There exists already a 2 percent tax on certified emission reductions created through the clean development mechanism of the Kyoto Protocol. Its revenues feed the Adaptation Fund and could reach between US$1 billion and $2 billion in 2020 depending on the restrictions imposed on the purchase of credits (Fankhauser and Martin 2010).[7]

What would the revenue effectiveness of a global carbon tax be? Worldwide CO_2 emissions from energy consumption amount to some 30 billion tons, of which about 15 billion tons come from high-income countries (US Energy Information Administration, International Energy Statistics). Thus, every dollar of tax per ton of CO_2 emissions in high-income countries would generate US$15 billion in revenues for the global fund. The middle range of the estimates of mitigation and adaptation costs in developing countries presented above, about US$220 billion, could be financed by a tax of US$15 per ton CO_2 in high-income countries.[8]

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[7] As of January 31, 2011, the Adaptation Fund, which was established in 2011 but really began operations after 2008, had received US$138 million from the CER tax and US$86 million from donors and other sources (AFB/EFC.4/10/rev.2).

[8] These estimates assume full compliance and they ignore the incentive effect of the tax. CO_2 emissions can be estimated to decrease by some 10 percent in developed economies for a tax of US$15 (Bicchetti et al. 2007, 25). We express all tax rates per ton CO_2. They can be converted into tax rates per ton carbon by multiplying them by 3.66.

Such back-of-the-envelope calculations ignore the incidence of the tax on its tax base. Revenue effectiveness is controversial for environmental taxes precisely because those taxes are initially designed to discourage a polluting activity, which is their own tax base. Of course, the kinds of global taxes considered in this chapter are not designed to eliminate the polluting activity entirely, but the tax base erosion effect ought to be taken into account. This is done in simulations with computable general equilibrium (CGE) models. Altamirano-Cabrera et al. (2010) start from different estimates of climate change impacts and adaptation costs in the literature. They retain climate change impacts of US$223 billion in 2040 for developing countries, or about 1 percent of their GDP. Financial compensation could be funded with a global tax of US$6.80 per ton CO_2 if all countries participated, or US$20 if participation were restricted to OECD countries. In the first case, world CO_2 emissions would decline as a side effect by 19 percent and in the second case by only 3.6 percent relative to baseline.[9] As a matter of fact, the tax restricted to OECD countries has CO_2 emissions growing by 2 percent relative to baseline in non-OECD countries due to lower demand for fossil fuels in the OECD, resulting in lower prices, and to some relocation of industrial production. The details of the simulation show the difficulties a tax restricted to the OECD will have in paying for worldwide climate change impacts. It would impose welfare losses on Australia, New Zealand and Canada equivalent to close to 2 percent of their total household consumption and it would imply annual

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[9] The revenues are paid lump-sum to the populations of the affected countries in proportion to their costs of climate change. This has only a marginal impact on emissions reduction. Emissions reduction is obtained by the incentive effect of the tax.

transfers of about US$100 billion from the United States mainly to India and other emerging countries in Asia aside from China. These economic impacts can be divided approximately by five if the global carbon tax is designed to cover adaptation costs in developing countries instead of their costs from climate change.

Financing adaption in developing countries is also the aim of the Swiss proposal to the Conference of Parties to the UNFCC: an international carbon tax of US$2 per ton CO_2 with a basic tax exemption of 1.5 ton of CO_2 per capita. Its estimated annual revenues of about US$18 billion would go into the Adaptation Fund.[10] This proposal beats other proposals that make the tax rate depend on the income level of each country in that it maintains the cost-effectiveness of climate mitigation (see below).

Another reference for financing needs is that of the additional resources required to reach the Millennium Development Goals, estimated at around US$50 billion per year on top of the US$57 billion provided currently under official development assistance, or ODA (Atkinson 2004). The fact that the revenues of the CO_2 tax would have to come on top of existing ODA hints at an important threat to this proposal:

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10 In the preparation of this proposal, Bicchetti et al. (2007) simulated an international carbon tax that would be sufficient to finance adaptation needs in the developing countries, estimating it at about US$10 billion in 2010 and rising to US$45 billion by 2040. The required tax would start at US$1 per ton CO_2 in 2010 and rise to US$4 in 2040. If the tax were restricted to OECD countries, it would have to start at US$3 and rise to US$13. In this case, world CO_2 emissions would decrease by less than 1 percent, whereas the worldwide tax generating the same revenues would obtain a decrease in CO_2 emissions by 6 percent in 2040.

countries might see their carbon-based contribution to the global fund as a substitute for their existing ODA and lower it (Sandmo 2004). The fact that the carbon tax would crowd out domestic tax revenues by eroding their tax base adds to the likelihood of such considerations.

<a>COST-EFFECTIVENESS

When several sources contribute to a common pool of pollution and each has the ability to lower its emissions, it seems to be desirable that those sources that can lower their emissions at the smallest cost provide the greatest reductions. This minimizes the total cost for a target amount of emissions reduction or, equivalently, allows the greatest reduction for the same budget. This will be discussed on a theoretical level before addressing the challenges of implementation.

For well-defined marginal abatement costs (MAC), total abatement cost is minimized when each source abates to the point where its MAC is equal to that of all other sources. So long as MACs are different, total cost can be lowered for the same mitigation result by having a source with lower MACs abate a little bit more and letting a source with higher MAC abate correspondingly less.

Of course, it is extremely difficult to estimate a national MAC, let alone a global MAC. Indeed, doing so would involve ranking all possible measures available to abate emissions, from the cheapest to the dearest. For simulation purposes, this is done by examining each measure individually (often a technology or a type of resource substitution), estimating the cost of abating different quantities of emissions with each measure (its MAC), and then constructing the outer envelope of these MACs, which defines the mix of measures that minimizes costs for each desired level of abatement. Setting a common mitigation target for several countries increases the portfolio of possible mitigation measures, which generally lowers the costs of reaching that target. Estimating MAC is necessary for setting optimal targets, based on a comparison of mitigation costs and benefits. The beauty of economic instruments such as environmental taxes is that they do not require any centralized knowledge of MAC. Indeed, they confront emitters with a common price for emissions, which induces each to compare her own mitigation options (i.e. MAC) with that price, thereby comparing them indirectly with the mitigation options of all other emitters facing the same price.

Equalization of MAC could be obtained by regulation if some authority were able and allowed to impose upon each source that amount of abatement that equates all MACs. It can be obtained much more easily by making sources pay a unit price for their emissions. Sources minimize their total cost—abatement plus tax on residual emissions —by selecting the quantity of abatement that equates their MAC to the unit price. Since that price is the same for all sources, all MACs are equated and least-cost mitigation obtains.

The uniform carbon price has the further attractive feature of rewarding continuous improvement. Indeed, as sources pay on residual emissions, contrary to regulation, they have an incentive to find new ways to reduce their emissions. This promotes the development, diffusion and adoption of innovation. Cost minimization at any point in time is called 'static cost-effectiveness,' while the pressure to improve continuously leads to 'dynamic cost-effectiveness.'

Transposed to a global environmental problem like CO_2 emissions, this suggests that global mitigation cost minimization can be enforced with a uniform carbon price. Every source of CO_2 emissions in the world should be charged the same price for each ton of CO_2 it emits (more precisely, for each quantity of greenhouse gases that has a warming potential equal to that of a ton of CO_2). If a global carbon tax allows the achievement of this, then it can be considered as efficient.[11] Any deviation from a uniform global carbon price would imply inefficient mitigation.

Full tax harmonization naturally obtains a uniform carbon price for all sources. In the case of the international tax, where countries are charged proportionally to their CO_2 emissions, a uniform carbon price for all sources obtains only if each country passes those costs down to all domestic sources. That means that in each country each source is made to contribute to the national bill in proportion to its contribution to national emissions. This amounts, in effect, to each country's introducing a domestic carbon tax at a rate equal to the international tax, which ends up being the same as tax harmonization.

The global costs of mitigation can be lowered substantially by its efficient division among all countries. Early simulations with four world models found cost savings in the range of 30 to 40 percent compared to a case where each country abates by itself (Weyant 1993). Later simulations with 13 improved integrated assessment models found even greater cost savings. Just allowing for the efficient apportionment of mitigation across the Annex I countries of the Kyoto Protocol lowers the required carbon tax by half compared to the tax if each country meets its target on its own (Weyant and Hill 1999). If developing countries are included, the required world tax, which measures the burden of mitigation indirectly because it is the common MAC, is

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[11] The uniform carbon price could also be achieved, in theory, by subsidizing emitters for emissions reduction or by forcing them to acquire emission permits on an efficient (i.e. single-price) market, provided the subsidy or the price of permits were the same worldwide.

four to nine times smaller than the stand-alone US tax for instance, depending on the model used (ibid.). The required carbon tax can be further reduced by 15 to 55 percent by including noncarbon greenhouse gases (Weyant, de la Chesnaye and Blanford 2006).

The substantial cost savings derived from including all countries in the global mitigation effort arise from the fact that developed countries are 'locked' in carbon-intensive infrastructures such as power plants, which cannot be replaced rapidly at low cost, whereas developing countries could follow a low-carbon growth path. However, these estimates do not account for many practical issues and market imperfections that stand in the way of cost-efficient sharing of the mitigation burden (Kolstad and Toman 2005).

There are many reasons to revise this ideal picture of the global carbon tax, even aside from its feasibility.[12] The first is related to fixed costs, which the comparison of MACs ignores. Forcing many small sources to reduce their emissions when each faces a fixed cost to start doing so may end up costing more than forcing large sources with possibly higher MACs to mitigate more. It could even cost more than the damage avoided. Administrative and compliance costs contribute to fixed costs. If

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[12] Baumol and Bradford (1970) show that optimal taxation of externalities differs from the internalization of those externalities under a budget constraint. Baumol and Oates (1988, Chapter 7), show further real-world interferences with the first-best ideal of equal MACs. In particular, the local (marginal) comparison of gains in abatement costs when they are reallocated between sources may not be representative of the global comparison of the actual production patterns with the social optimum.

these costs vary by source, they should be taken into account in the comparison of MACs.[13] The ideal picture also breaks down when large or numerous small sources do not minimize their total costs—abatement plus tax. One can imagine many situations where they would not: nonoptimizing behavior, imperfect information, split incentives (whoever decides is not the one who pays, for instance in rental housing), market power, or subsidies (including public or semipublic enterprises).[14]

Further problems with the ideal picture appear at the international level. The model assumes that abatement costs can be compared worldwide, as though there existed a single world market with a single world price for the resources needed for abatement. That might be true for commodities such as oil and gas, which are traded worldwide, but not for less mobile resources such as physical capital and labor. Barriers to trade and the diffusion of technologies and know-how jeopardize static and

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[13] OECD (2009) cites deforestation and methane emissions resulting from pipeline leakage as sources with high monitoring and enforcement costs.

[14] OECD (2009, 100) estimates that 'removing environmentally harmful fossil fuel energy subsidies, especially in non-OECD countries is an important first step. This would reduce greenhouse gas (GHG) emissions drastically in the subsidized countries, in some cases by over 30 percent relative to business-as-usual (BAU) levels by 2050 and it would also raise GDP per capita in most of the countries concerned. A multilateral removal of energy subsidies would cut GHG emissions globally by 10 percent by 2050 relative to BAU and this cut could be increased if developed countries adopt binding emission caps. The removal of energy subsidies would lower the cost of achieving a given mitigation target.'

dynamic cost-effectiveness. Suppose it took one man-hour to abate one ton of CO_2 in the United States and two man-hours to do it in China. Should one conclude that more mitigation ought to be performed in the United States? United Nations Industrial Development Organization (1972) and Dasgupta (1972) recommend using domestic shadow prices, reflecting opportunity costs in terms of foregone domestic consumption, to assess projects.

Even if abatement costs were perfectly comparable across countries, it is not obvious that the kind of total abatement cost minimization that a uniform tax would bring corresponds to a welfare optimum (Chichilnisky and Heal 1994; Chichilnisky 1994; Hourcade, Helioui and Gilotte 1997). If any country were to set its carbon tax in autarky, it would compare the marginal cost of mitigation, in terms of foregone consumption utility for its population, with the marginal benefits of smaller (future) climate change. Every one of these determinants of the optimal domestic carbon tax differs between countries. In low-income countries, the balance tilts strongly on the side of mitigation costs, so they would select a much lower tax than would high-income countries.[15] A uniform world carbon tax would be too high for low-income countries and too low for high-income countries. It seems that the only way to agree on the total abatement cost minimization solution of the uniform tax is to transfer revenue from high- to low-income countries. The transfers would not need to equate income levels but they would need to compensate for the differentials in burdens imposed by the cost-minimizing solution. Absent such transfers, a solution with differentiated carbon taxes is closer to a second-best option (Sandmo 2004).

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[15] This argument is equivalent to the personalized Lindahl contributions to the costs of a public good (Hinchy and Fisher 1999).

A further complication derives from the fact that the greenhouse effect is not the only motive for taxing fossil fuels. Their burning generally causes local damage, mainly through air pollution. In addition, many countries tax fuels for revenue purposes, whether because they cannot impose less distorting taxes or because they want to link payment to the use of public goods (such as a tax on gasoline and diesel to pay for roads). With preexisting fuel taxes, a uniform carbon tax such as the harmonized carbon tax does not equate marginal abatement costs (Haugland, Olsen and Roland 1992). Hoel (1993a) has shown how the other motives ought to be taken into account in determining the optimal national taxes on fossil fuels. As a result, the full optimal taxes on fossil fuels are quite different from country to country, even when the part that corresponds to the greenhouse effect, the carbon tax, is harmonized. It is not even the case that the harmonized carbon tax should simply be added on top of the preexisting taxes, because the higher tax reduces emissions, moving the country down the marginal damage curve for local pollution, and increases the deadweight loss. It is therefore quite defendable to lower preexisting fuel taxes when introducing the carbon tax. Of course, it is extremely hard to distinguish that adjustment from a country's compensating reductions because it would rather free-ride on other countries' carbon mitigation than pass the full cost of the carbon tax onto its citizens.

The design with the international tax is not exempt from similar problems. Indeed, it determines only how much each participating country must contribute to the common fund in proportion to its emissions, not how it finances this contribution. It might for instance exempt its trade-exposed sectors and impose taxes more heavily on the emissions of sheltered sectors. That would destroy both gains from trade and cost-effective mitigation. Although this is a clear breach of trade principles, it remains that it is not necessarily optimal for a country to impose a uniform tax on all its emissions sources equal to the international tax, for the same reasons that the harmonized carbon tax does not imply equal optimal domestic taxes on fossil fuels (Hoel 1993b).

<a>FAIRNESS

Focusing on environmental- and cost-effectiveness is acceptable for small national environmental taxes because other social mechanisms or the potential redistribution of the net gains from the policy can be invoked to address their burden on low-income households. Such an argument is much harder to defend at the international level, where the disparity in incomes is even greater and where there are very few redistributive mechanisms (Wiener 1999). On the other hand, actual redistribution and compensation is much more likely with a global tax because countries must be made to participate voluntarily.

It is necessary to consider three elements in assessing the fairness of a global environmental tax: (1) the direct economic burden for each country, (2) the revenue share received by each country, and (3) the environmental benefits for each country. The last impact is of course the hardest to estimate, as still very little is known about the likely costs of climate changes and about how and at what costs they could be mitigated by adaptation measures. The direct economic burden is estimated with the use of general equilibrium models, which are designed to capture the many channels through which a carbon tax could affect a nation's production and consumption, including international effects such as impacts on terms of trade. Early estimates on such an issue are those of Whalley and Wiggle (1991a), and, in more detail, Whalley and Wiggle (1991b), which show that the burden on each region (three world regions in the first paper, six in the second) depends very much on the format of the global carbon tax and the rules for revenue redistribution. Countries that are significant net exporters of fossil energy (such as OPEC countries) would benefit strongly from harmonized taxes levied at the well, with no international redistribution of the revenues, because that would amount to a coordinated price increase. Symmetrically, net importers of fossil energy would benefit from harmonized taxes levied on emissions, with no international redistribution, because that would improve their terms of trade, like a buyers' cartel. Finally, an international tax with revenues redistributed to countries in proportion to their populations would greatly benefit the least developed ones, thanks to huge transfers from North to South. Those countries would suffer from the harmonized tax regimes.

The importance of compensatory redistribution is made evident by the large differences in abatement costs across regions if a harmonized carbon tax is imposed, even if its revenues stay in each country. Figure 25.3 shows estimates of those net costs, taking into account general equilibrium effects such as terms-of-trade changes and trade flows (TOCSIN research team 2009). The simulations were performed with a state-of-the-art model coupling the worldwide computable general equilibrium model GEMINI-E3 and the bottom-up technology model TIAM after carefully updating them with the best available data for China and India. The costs of mitigation are those obtained with a harmonized tax on all greenhouse gas emissions that would control them so that radiative forcing never exceeds 3.5 W/m^2. All countries are assumed to participate and to recycle their tax revenues in lump-sum fashion to their population. The costs of mitigation are measured in terms of GDP, consumption and consumer surplus loss.[16] Climate change impacts and adaptation are not considered. Mitigation costs are greatest for the fossil-fuel exporters Russia and the Middle Eastern countries, but they are also relatively high for Africa, while the most advanced Asian and European countries bear no net costs at all.

[Insert Figure 25.3 about here]

A well-drafted global environmental tax creates surplus relative to the no-policy alternative, which can be used for the actual compensation of the losers. This global surplus is the difference between avoided environmental damage and adaptation costs on the one hand and mitigation costs on the other hand. However, avoided damage costs are a hard-to-mobilize source of transfers, particularly when they occur in the distant future. Many countries, particularly the least developed ones, place much greater weight on current mitigation costs rather than on future avoided climate change costs. They call for a fair sharing of mitigation costs. Figure 25.3 does not suggest that mitigation costs are shared fairly under a global carbon tax, whatever one's definition of fairness is. The kind of redistribution needed to ensure voluntary participation ought to make sure that no participant is worse off under the global tax regime, a minimal condition of fairness.

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[16] GDP loss is the sum of discounted GDP losses relative to the no-policy baseline until 2100. Consumption loss is the sum of discounted variations in household consumption. Surplus loss is the sum of discounted annual consumer surplus divided by the present value of household consumption in the baseline.

<a>COMPLIANCE

A global environmental tax raises new compliance issues compared to the textbook national tax. To begin with, it might have to be enforced by developing countries that might lack the required institutions. Second, the global tax would be imposed without any superior authority that could ensure compliance, even though each country would have an incentive to free-ride on other countries' efforts. A country might have decided to participate, maybe in exchange for some compensatory transfer or other advantage granted by other countries, but it might still want to cheat on its commitments. In the case of the international tax design, it must agree to contribute to the global fund based on its actual emissions. In the case of the harmonized tax design, it must agree to tax all of its domestic sources even though it might wish to protect some sectors.

Developing countries might be even further away from the textbook model of optimal Pigouvian taxation than are developed countries. Their markets are less efficient; they have greater difficulty in preventing tax evasion and making sure that effective and statutory tax rates coincide; and they typically lack the means to offset the adverse distributional consequences of environmental taxes (Blackman and Harrington 2000; Sandmo 2004). Nonetheless, a carbon tax is not the most difficult environmental tax to implement because it need not be charged on actual emissions. It can be levied at the border, on the imports of fossil fuels, and, if applicable, at the point of extraction.

This does not address, however, the issue of the heavy burden falling on particularly fragile households or firms. Participating countries might want to protect them against the hardships of the global tax. They also might want to protect particularly polluting or resource-intensive sectors, especially if those sectors are exposed to international competition. These are strong motives for noncompliance with the harmonized tax. The hidden means for such 'domestic cushioning strategies' (Wiener 1999, 785) are numerous: offsetting tax cuts, indirect subsidies such as free land rights, and so forth. In the case of carbon taxation, almost all countries apply other direct and indirect taxes and subsidies on fossil energy, which can be perfectly justified by the internalization of local external effects or revenue purposes and which can easily be modified by arguing that those motives changed (Hoel 1992; Hoel 1993a). They actually do change when a carbon tax is introduced!

Clearly, international enforcement of compliance with harmonized taxation would be extremely difficult and would imply deep scrutiny into domestic tax practices.[17] The incentives for cushioning and the difficulty of detecting it are greater under the harmonized tax regime than under a quota regime, which would force countries to compensate for the exemptions granted to some sectors and which would not impose a burden on polluters beyond the mitigation costs (Wiener 1999, 786). On the other hand, a country that is lenient with its polluters under a system of internationally tradable quotas allows them to sell more permits for foreign cash, which increases the risk of corruption (Nordhaus 2006, 34).

The international tax design faces compliance difficulties too. It requires precise monitoring on national emissions. For CO_2, countries already contribute data to national emissions inventories, which is not very complicated (the algorithm is thus: measure the extraction of fossil fuels plus imports minus exports). Things are more

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[17] Cooper (1998) argues that the IMF could monitor enforcement of the harmonized tax, as it holds annual consultations with nearly all countries in the world on their macroeconomic policies, including their tax revenues.

complicated when carbon sequestration and the emissions from cement production are to be taken into account, and even more so when the tax is extended to other greenhouse gases. These issues are not different, however, for the international tax than for an agreement on quantities or a cap-and-trade regime.

<a>CONCLUSION: PROSPECTS FOR IMPLEMENTATION

There are two main formats for a global tax: a harmonized tax, which each participant country imposes at the same rate on all its domestic emitters, and an international tax, which each participant country pays into a common fund in proportion to its total emissions. We have assessed global taxes and have compared the two formats with respect to five criteria: environmental-effectiveness, revenue-effectiveness, cost-effectiveness, fairness and compliance. The main results are summarized in Table 25.1.

[Insert Table 25.1 about here]

Where does this leave us with respect to the likelihood of implementation? Clearly there are great challenges related to all criteria, but also great potential, in particular for generating the large revenues that developing countries will increasingly need in order to address the effects of climate changes. Should revenue generation become the main argument for a global environmental tax on which all countries can agree, then the international tax would be the natural design. Most likely it would be a small tax and it would be levied mostly on higher-income countries, or possibly on all countries as they pass an income-per-capita threshold. Such a tax would not do much for climate change mitigation.

If climate change mitigation remains the main purpose of the global tax, then harmonized national taxes would be the more natural and likely design.[18] It is much easier for countries to agree on a set of actions, in particular harmonized carbon taxes, than on quantitative targets such as national emission targets (Cooper 2000). Tax harmonization is flexible in that it can start with a nucleus of first movers who simply align their internal carbon taxes at a common rate, without the need to create new institutions or conduct controversial negotiations about such things as emission quotas. New participants can join at any time by simply introducing the same carbon tax. This might lead the coalition to revise its climate policies and modify technology and financial transfer rules, in accordance with the 'bottom-up approach' of Bodansky et al. (2004). Complete adherence of all countries is not necessary, but the circle of participants ought to be extended gradually to increase environmental- and cost-effectiveness. Dedicating part of the revenues of the harmonized carbon tax to a common pool that helps newcomers would accelerate adherence.

This progressive approach can draw on the international diplomatic experience with the harmonization of tariffs (Nordhaus 2006).[19] It is similar to the EU's 'opting

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[18] OECD (2009) sees the most promising way toward a global carbon price in the linking of domestic and regional emission trading schemes. This approach would suffer, however, from the new skepticism in global financial markets, which have shown that they spread shocks around the globe, and the new skepticism in a common currency, since emission permits would be a common currency.

[19] Incidentally, tariff harmonization could lead to the harmonization of domestic carbon taxes. Indeed, countervailing import tariffs (border tax

out' and 'flexible geometry' rules. EU climate policy, in particular its emissions trading scheme, shows that (groups of) countries are willing to take a first step to address climate change even when other big emitters opt out (such as the United States) or are allowed to not participate (developing countries). Similar unilateral first moves, later followed by cooperation, have been observed in other areas: trade, disarmament, phasing-out of ozone-depleting substances etc. (Pizer 2009). There are advantages for first movers in a repeated game context where there is a good chance that some cooperation will ultimately ensue. The first movers might be countries for which the balance of benefits (including internal benefits such as reduced pollution and terms-of-trade gains) and costs is more favorable. More research might be needed on such gradual implementation of a global environmental tax and the conditions for 'coalitions of the willing' to emerge.

The EU is probably the best place to experiment with harmonized national taxes. It has experience with tax harmonization, in particular value-added taxation (Padilla and Roca 2004). On the other hand, the EU has tried and failed in the past to agree on a common carbon tax. The Commission of the European Communities had put such a proposal to the Council in 1992, a tax starting at about US$7 per ton CO_2 and rising gradually to US$22 (Delbeke 1994). This shows that it is easier to harmonize taxes that all countries already have in some form or other, which is not the case with

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adjustments) require equivalent carbon taxes on domestic production under WTO regulation. When these import tariffs are harmonized, this leads automatically to harmonized domestic carbon taxes.

carbon taxation (Baranzini, Goldemberg and Speck 2000).[20] As a result, passing carbon tax legislation is a first step that each country must take on its own before it can join the coalition.

The harmonized tax format faces the problem of preexisting taxes on fossil fuels and compensating subsidies on complements. This problem is not negligible, as countries use a wide array of significant taxes and subsidies related to fossil fuels. The only practical solution seems to be to agree on some minimum tax on fossil fuels and let each country decide how it wants to incorporate financing motives or the internalization of local external effects, and how it wants to compensate the users of fossil fuels for the income effects. Lower carbon tax rates in developing countries can be defended following second-best arguments as long as large transfers from developed countries do not compensate them for the heavy mitigation burden imposed on them (Sandmo 2004). Here again, more research is warranted to find practical rules for differentiated harmonized taxes that replace the uniform-emissions-price mantra by taking into account all the subtleties of the real world.

One interesting attempt at harmonization originates again in the European Union. In May 2011, the European Commission issued proposals to regulate transport and heating fuel taxation in the Union, not just by setting minimum rates but also by defining a common tax base. By these proposals, fuel taxes should be the sum of a component based on energy content and a component based on CO_2 emissions. The latter would be a uniform 20 Euros per ton from 2013, close to the expected carbon price in the EU ETS.

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[20] The OECD maintains a database on environmentally related taxes and other instruments: http://www.oecd.org/env/policies/database.

In the meantime, there should be some agreement to gradually phase out all forms of harmful subsidies to fossil fuels. This could be achieved in a multilateral fashion, similar to the removal of barriers to trade. Non-OECD countries are the most concerned. The removal of these subsidies could lower greenhouse gas emissions from fossil fuels combustion by 30 percent relative to business-as-usual levels by 2050 (OECD 2009).

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