Fiscal Policy to Mitigate Climate Change

A Guide for Policymakers

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Summary for Policymakers

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Scientific evidence suggests that climate change is an extremely serious threat (see Box I.1) and that a major international effort to slow atmospheric accumulations of greenhouse gases (GHGs) over the twenty-first century is a key component of the appropriate policy response. If left unchecked, climate change could have increasingly serious macroeconomic consequences—especially in countries with limited ability to adapt to hotter temperatures, higher sea levels, diminished water supplies, and so on.

Many countries have made emissions control pledges, and parties at the December 2011 climate change meetings in Durban, South Africa, pledged to develop a global emissions control agreement to be implemented in 2020. However, until there are credible mechanisms for enforcing such commitments, it is not entirely clear that the Durban platform will deliver on its promise, in which case climate policies will continue to emerge in a piecemeal "bottom up" fashion for the foreseeable future. Either way, the implementation of mitigation policy is only just beginning: Over 90 percent of global GHG emissions are presently not covered by formal mitigation programs.

In responding to this challenge, it is critical to use the most *effective* emissions control instruments, namely those that exploit all potential possibilities for reducing emissions, rather than using narrowly focused policies that miss out on a lot of these opportunities. It is also important to use policies that contain mitigation *costs* (for a given emissions reduction), not only for its own sake, but also to improve the prospects for sustaining policies over time.

The instrument that best fits these two criteria is revenue-raising carbon pricing—carbon taxes or cap-and-trade systems with allowance auctions—so long as it is well designed in terms of comprehensively

Box I.1. The Climate Change Challenge

Annual global CO_2 emissions from fossil fuels have grown from about 2 billion tonnes in 1900 to about 30 billion tonnes today, and, in the absence of mitigation policies, they are projected to roughly triple 2000 levels by the end of the century. The huge bulk of the projected future emissions growth is in developing countries: CO_2 emissions from these countries now exceed those from industrial countries; by 2030, China and India combined are expected to account for about one-third of global emissions. Land-use changes (primarily deforestation) will contribute about an additional 5.5 billion tons of CO_2 releases, though these sources are projected to grow at a much slower pace than fossil fuel emissions.

Atmospheric CO_2 concentrations have increased from preindustrial levels of about 280 parts per million (ppm) to current levels of approximately 390 ppm, and they are projected to rise to about 700 to 900 ppm by 2100. About one-half of CO_2 releases accumulate in the atmosphere (the rest are absorbed by sinks, especially the oceans and forests). Accounting for non-CO_2 GHGs, such as methane and nitrous oxides, the CO_2-*equivalent* atmospheric concentration is about 440 ppm. Total GHG concentrations in CO_2-*equivalents* are projected to reach 550 ppm (i.e., about double preindustrial levels) by around mid-century.

The globally averaged surface temperature is estimated to have risen by about 0.75° C since 1900, with most of this warming due to rising GHG concentrations. If CO_2-*equivalent* concentrations were stabilized at 450, 550, and 650 ppm, mean projected warming over preindustrial levels is 2.1° C, 2.9° C, and 3.6° C, respectively, once the climate system stabilizes (which takes several decades). Actual warming may exceed (or fall short of) these projections due to poorly understood feedback in the climate system.

The physical consequences of warming include changed precipitation patterns, sea level rise (amplified by storm surges), more intense and perhaps frequent extreme weather events, and possibly more catastrophic outcomes like runaway warming, melting of ice sheets, or destruction of the marine food chain (due to warmer, more acidic oceans). Estimates of the damages from these effects are highly uncertain due to difficulties in valuing low-probability, catastrophic events; uncertainty over regional climate effects (including the risk of shifting monsoons and deserts); and uncertainty over regional development, technological change (including adaptive technologies like climate and flood-resistant crops), and other policies (e.g., attempts to eradicate malaria or integrate global food markets). Worldwide impacts also mask huge disparities in regional burdens—hotter, low-lying, and low-income countries are most at risk and are most lacking in adaptive capability, while some wealthy, more temperate countries could benefit (e.g., from longer growing seasons).

Sources: Chapter 3, IPCC (2007), and Aldy and others (2010).

covering emissions. Revenues from these fiscal instruments can contribute significantly to fiscal consolidation needs—if countries do not implement such policies, they will need to rely more heavily on other deficit reduction measures.

However, policymakers may need to consider many questions in crafting carbon pricing legislation. These include the following:

- How strong is the case for carbon pricing instruments over regulatory approaches (e.g., standards for energy efficiency or mandates for renewables), how do carbon taxes and cap-and-trade systems compare, and what might be some promising alternatives if "ideal" pricing instruments are not viable initially?
- How is a carbon pricing system best designed in terms of covering emissions sources, using revenues, overcoming implementation obstacles (e.g., by dealing with competitiveness and distributional concerns), and possibly combining them with other instruments (e.g., technology policies). And how might pricing policies be coordinated across different countries?
- How should policymakers think about the appropriate level of emissions pricing?
- How important is inclusion of the forest sector in carbon pricing schemes, and how feasible is this in practice?
- What should be the priorities for developing economies in terms of fiscal reforms to reduce emissions?
- From the perspective of raising funds (from developed economies) to fund climate projects (in developing economies), what are the most promising fiscal instruments and how should they be designed?
- What lessons can be drawn from experience with emissions pricing programs, like the European Emissions Trading System (ETS), or the various carbon tax programs to date?

Although the IMF is not an environmental organization, environmental issues matter for our mission when they have major implications for macroeconomic performance and fiscal policy. Climate change clearly passes both these tests, and in fact recent IMF work has addressed a variety of fiscal issues posed by climate and broader environmental challenges.[1] Continuing this work, in September 2011 the IMF's Fiscal Affairs Department held an expert workshop at which eight policy notes covering the above, and some other, issues in designing carbon pricing policies were presented for discussion and comment. This volume collects the final versions of these policy briefs.

To be sure, there are numerous other discussions on the design of climate mitigation policies. However, this volume differs because of its especially in-depth coverage of issues for *fiscal* policies and provision of specific, readily implementable, policy recommendations. Other components of the appropriate response to climate change, including adaptation policy, improving scientific knowledge, and developing "last-resort" technologies for use in extreme climate scenarios, are beyond our scope.[2]

The rest of this summary draws out some of the main take-home lessons for policymakers from the different chapters in this volume. Most of these lessons are actually fairly straightforward—climate policy design is not as complicated as it might first appear.

Lessons from Chapter 1: Comprehensive Carbon Pricing Policies Can Effectively Reduce Emissions and at Least Cost

Comprehensive carbon pricing measures exploit the entire range of emissions reduction opportunities across the economy. As the emissions price is reflected in the prices of fossil fuels, electricity, and so on, this promotes fuel switching in the power sector and reductions in the demand for electricity, transportation fuels, and direct fuel usage in homes and industry. Carbon pricing also strikes the cost-effective balance between different emission reduction opportunities because all behavioral responses are encouraged up to where the cost of the last tonne reduced equals the emissions price. Moreover, the carbon price provides a strong signal for innovations to improve energy efficiency and reduce the costs of zero- or low-carbon technologies. By definition, regulatory policies on their own, like mandates for renewable fuel generation and energy efficiency standards,

[1] This work covers, for instance, the macroeconomic, fiscal, and financial implications of climate mitigation and adaptation policies; the appropriate design of fuel and other environmental taxes; the measurement of energy subsidies and protection of the poor when they are scaled down; border tax adjustments; and the taxation of resource industries. For more information see www.imf.org/external/np/exr/facts/enviro.htm.
[2] "Last-resort" technologies include "air capture" filters to absorb CO_2 from the atmosphere and store it underground (at present, these technologies are unproven and very costly). They also include "geo-engineering" technologies, like solar radiation management (shooting particulates into the atmosphere to deflect incoming sunlight), which are inexpensive to deploy and could entail dangerous downside risks (e.g., the possibility of overcooling the planet).

are far less effective as they focus on a much narrower range of emission reduction opportunities. Regulatory policies can also impose excessive costs unless they are accompanied by provisions allowing firms with high emissions control costs to purchase emission reduction credits from firms with low emission control costs. Given the scale of the challenge—reducing emissions to a minor fraction of "business-as-usual" emissions over coming decades—choosing the most effective and cost-effective mitigation instruments is critically important.

The choice between carbon taxes and emissions trading systems is generally less important than implementing one of them and getting the design details right. Key design specifics include comprehensively covering emissions and avoiding the squandering of revenue potential (e.g., by granting free allowance allocations in cap-and-trade systems or earmarking revenues for socially unproductive purposes). For cap-and-trade systems, provisions are also needed to limit price volatility, and these systems are not appropriate for countries lacking institutions to support credit trading.

If carbon pricing policies are not initially viable, carefully designed regulatory packages or, better still, "feebates" can be reasonable alternatives. Combining a carbon dioxide (CO_2) per kilowatt hour standard for the power sector with energy-efficiency standards for vehicles, appliances, buildings, and so on can promote many of the emission reduction opportunities that would be exploited by carbon pricing policies. And regulatory policies avoid large (politically challenging) increases in energy prices as they do not involve the pass-through of large carbon tax revenues (or allowance rents) in higher prices. But again, extensive credit-trading provisions across firms and sectors are important for containing the costs of these regulatory packages. More promising is to use feebate or tax/subsidy analogs of these regulations (e.g., taxes for generators with high emissions intensity and subsidies for generators with low emissions intensity), as these policies circumvent the need for credit trading. Regulatory or feebate policy packages should still transition to carbon pricing whenever feasible, however, to raise government revenue, more comprehensively reduce emissions, and facilitate international coordination.

Lessons from Chapter 2: Design Details for Carbon Pricing Are Important

Targeting the right base for carbon pricing is critical for environmental effectiveness. Ideally, carbon prices are applied in proportion to the carbon content of fuels as they enter the economy (e.g., from petroleum refineries, coal mines, fuel importers), with refunds for carbon capture technologies installed at industrial facilities. Pricing the carbon content of fuels at different rates, or varying the price across fuel users, undermines cost-effectiveness by placing an excessive burden of reductions on the heavily taxed fuel or end user and too little burden on other fuels or other users. Electricity taxes are a poor substitute for carbon pricing on environmental grounds, as the former miss out on the huge bulk of emissions mitigation opportunities. Pricing emissions at the point of fuel combustion (e.g., power generators, industrial boilers) involves monitoring many more entities and some loss in coverage (e.g., small-scale emitters are usually exempt). Some non-CO_2 GHGs might be covered directly under the pricing regime or indirectly through emissions offset credits, as capability for monitoring and verification is developed over time.

The costs of comprehensive carbon pricing is initially modest if revenues are used productively. Productive revenue uses include reducing taxes on work effort and capital accumulation, retiring public debt, and funding socially desirable (environmental or other) public spending. With productive revenue use, the overall costs of (appropriately scaled) carbon taxes to the economy are modest in the medium term, typically around 0.03 percent of GDP for developed economies. If revenues are squandered, however, policy costs can be several times higher.

Although carbon pricing is the most important measure for promoting clean technology development and deployment, supplementary technology policies may be warranted, though they need to be carefully designed. For example in cases where, despite carbon pricing, clean technology deployment could be too slow because of further "market failures," additional transitory incentives may be appropriate. Pricing incentives (e.g., technology adoption subsidies) are generally better able to handle uncertainty over future technology costs than technology mandates that force a technology, regardless of future conditions.

Some options for overcoming opposition to carbon pricing do exist. Higher energy prices hurt consumers and reduce the competitiveness of trade-exposed, energy-intensive firms (e.g., aluminum and steel producers). However, these effects should not be overstated and might be addressed in part through scaling back preexisting energy taxes (particularly on vehicles and electricity consumption) that become redundant with carbon pricing. Another possibility is to compensate through the broader fiscal system (e.g., in Australia, revenues from carbon pricing will fund an increase in personal income tax thresholds to especially help low-income households). Competitiveness concerns might be addressed through transitory production subsidies for vulnerable firms (this is better than granting these sectors preferential fuel prices). Border tax adjustments are another possibility, though they may run afoul of free trade obligations.

At an international level, a price floor among large emitting countries is a potentially promising way forward. Reaching an international agreement over a common CO_2 price and how it might respond to future evidence on global warming may be less difficult than agreeing on annual emissions targets for each participating country. Prospects for agreement might be enhanced further if the policy took the form of a floor price, which provides some protection for countries willing to set relatively higher carbon prices.[3] Although countries would forgo controls over annual emissions, pricing agreements might be combined with maximum allowable emissions cumulated over, say, a 10-year period (requiring increases in their carbon price if they are not on track to stay within the "carbon budget"). An agreement would need provisions (e.g., monitoring by an international body) to deal with the possibility that individual countries may adjust their broader energy tax/subsidy provisions to undermine some of the effectiveness of the formal carbon price.

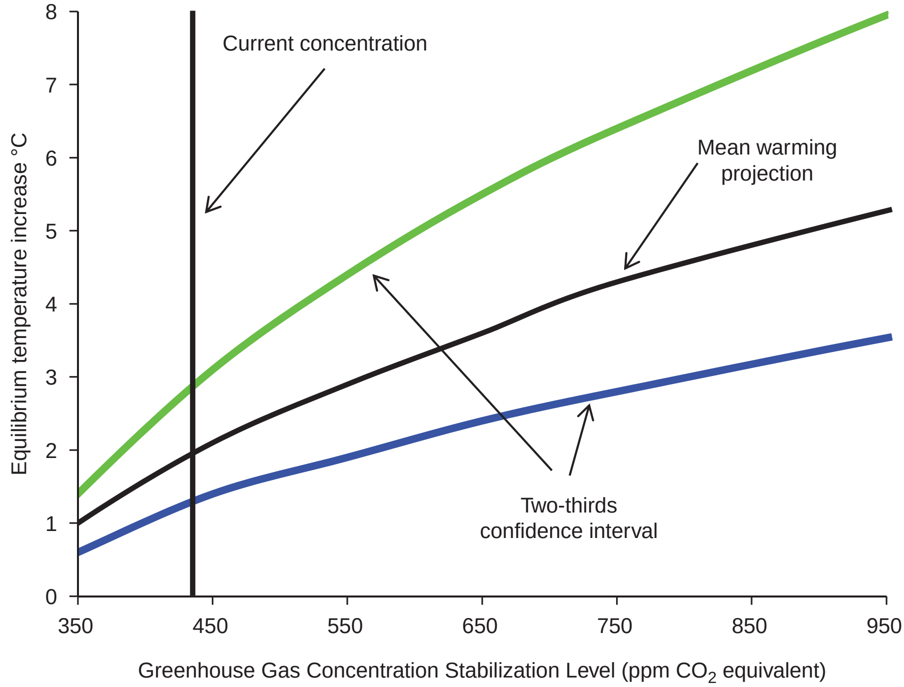
Lessons from Chapters 3 and 4: Studies Suggest that a Reasonable Starting Level for Emissions Prices in Large Emitting Countries Would Be about US$20 Per Tonne of CO_2 or More by 2020

There are two basic ways to think about the appropriate price on CO_2 (and other GHGs). One is to define an ultimate goal for global climate stabilization—usually a target for mean projected warming above the pre-industrial level (that might, for example, be the result of a political process, of an ethical principle, or of a precautionary approach)—and impose emissions pricing paths that are consistent with meeting this target, ideally in a way that minimizes mitigation costs. The other is to impose emissions prices that reflect potential environmental damages per tonne of emissions. Despite considerable uncertainties and controversies, broad policy guidance can still be provided under either paradigm.

Limiting long-term, mean projected warming to 2° C above preindustrial levels—the official goal of the UN Framework Convention on Climate Change—is highly ambitious and may be infeasible. As indicated in Figure I.1, atmospheric concentrations of GHGs would need to be stabilized at about 450 parts per million (ppm) of CO_2 equivalent (or close to current levels) in order to keep projected warming to 2° C. After an inevitable period of "overshooting" this concentration level, global GHG emissions would need to be negative on net for a sustained future period to bring CO_2 equivalent

[3] Alternatively, a common floor price might be agreed among countries implementing cap-and-trade systems, without necessarily any agreement over country-level emissions caps.

Figure I.1. Projected Long-Term Warming above Preindustrial Temperatures from Stabilization at Different Greenhouse Gas Concentrations



Source: IPCC (2007), Table 10.8.

concentrations back down to 450 ppm. Whether negative emission technologies (e.g., use of biomass in power generation coupled with carbon capture and storage) can be developed, let alone deployed on a global scale, to more than offset other GHG emissions, is highly speculative.

Less stringent targets, for example, keeping mean projected warming to 2.9° C or 3.6° C, are more plausible, but also more risky. These warming targets require stabilizing atmospheric GHG concentrations at approximately 550 or 650 ppm of CO_2 equivalent, respectively, and global emissions prices in the ballpark of US$40 and US$20 per tonne by 2020, respectively. Relative to business-as-usual outcomes, these stabilization targets substantially reduce the risk of more extreme climate outcomes—but this risk is not eliminated (underscoring the need for investment in last-resort technologies). Postponing mitigation actions, especially in emerging economies, can greatly raise the global costs of climate stabilization and render more stringent targets infeasible. For example, the 550-ppm target becomes technically out of reach if action by all countries is delayed beyond 2030.

Encouraging the major emitting developing economies to reduce GHGs could be facilitated by compensation payments. This might take the form of direct side payments (under a tax regime) or generous emissions allocations (under a trading system), though both are challenging to negotiate. In the meantime, the Green Climate Fund (GCF) could catalyze financial flows to developing economies, underscoring the need for innovative sources to finance the GCF.

As policies emerge piecemeal (rather than as part of an internationally agreed stabilization goal), it might be more natural to base the emissions price on the social cost of carbon (SCC). The SCC is the discounted monetary value of the future climate change damages due to an additional tonne of CO_2 emissions. A recent U.S. government study (in their central case) recommended a value of $21.4 per tonne of emissions released in 2010 (in 2007 U.S. dollars), rising at about 2 to 3 percent per year in real terms (i.e., this price is roughly consistent with near-term prices for stabilizing projected warming at 3.6° C). These estimates are based on an extensive assessment of models combining simplified representations of the climate system with dynamic models of the global economy. Damages reflect, for example, future impacts on world agriculture, costs of protecting against rising sea levels, health effects (e.g., from heat waves), ecological impacts (e.g., species loss), and risks of more extreme damage outcomes.

The SCC is sensitive, in particular, to alternative perspectives on discounting and extreme climate risks. Global warming is an intergenerational problem because emissions have long atmospheric residence times (about 100 years in the case of CO_2), and the full warming from higher atmospheric concentrations is not felt for several decades (due to gradual heat diffusion processes in the oceans). Reports by the U.K. and German governments, for example, have cautioned against discounting impacts on future (unborn) generations on ethical grounds, in which case the SCC is much higher. The SCC can also be much higher if more weight is attached to the risk of extreme climate outcomes or if impacts on low-income countries are given a disproportionately high weight. Nonetheless, individual countries may be reluctant to price emissions much above US$25 per tonne, in the absence of similar pricing by other countries.

SCC values can be applied to other major emitting countries based on purchasing power parity exchange rates. Ideally, emissions from different countries should be priced at the same rate as they cause the same damage. Arguments can be made for exempting (low-emitting) developing economies (see below), for example if compensation payments (from wealthier countries) are not feasible.

Given the scope for future learning about the seriousness of climate change, establishing emissions pricing in the high-emitting countries over the next several years is more important at this stage than negotiating over long-range targets. Once pricing policies have been established, they can be adjusted as needed in the future as greater consensus emerges on the urgency of climate stabilization. A reasonable minimum price to aim for seems to be around US$20 per tonne, under either least-cost climate stabilization or damage valuation approaches. Establishing a credible time path for progressively rising carbon prices is also important to create stable incentives for long-term, clean energy investments.

Lessons from Chapter 5: National Payments for Forest Carbon Sequestration Are Promising if Carbon Can Be Measured

Potentially, forest carbon sequestration could account for about a quarter of global CO_2 mitigation over this century. This carbon storage could be achieved through a combination of reduced deforestation, afforestation, and changes in forest management, primarily in tropical regions.

Although a host of small programs can promote forest carbon sequestration, national programs are easier to administer. Scaling up small projects is difficult, given limited technical capacity (e.g., that of NGOs) and the risk of leakage (e.g., reduced deforestation in one area offset by increased deforestation elsewhere). Moreover, judging whether sequestration projects are "additional" (i.e., whether they would have gone ahead even without the program incentive) can be difficult (implying the possibility of "wasted" program funds). National programs are more promising ideally with coordination (e.g., harmonized emissions prices) among the major tropical forest countries (national programs also allow flexibility for governments to deal with multiple claimants over forest land).

Baselines need to be carefully chosen, however. One (national-level) possibility is tax-subsidy schemes (with periodic updating of baselines). For example, payments could be offered for increases in sequestered carbon on particular parcels of forest land over and above the sequestered amount in some baseline year, and charges could be applied to other parcels where sequestered carbon falls below the baseline level. The scheme would be approximately revenue neutral (even though some sequestration activities may not be additional). Measuring sequestered carbon can be difficult, however (e.g., it varies with species, tree age, and selective harvesting), and is not permanent. In cases where reliable estimates of carbon storage are lacking, payments may need to be based on some proxy for CO_2, like forest coverage, with adjustments for tree species and local climate. Ideally, payments are made on an annual basis to deter, for example, early harvesting and inadequate safeguards against fire hazards.

Lessons from Chapter 6: Small-Emitting Developing Economies Should Focus First on Energy Pricing Reforms that Are in Their Own Interest

Most low-income countries contribute very little to current and projected future CO_2 emissions and the case for them to undertake costly mitigation policies is correspondingly weak. Low-emitting developing economies nonetheless have a critical role in finding an effective and efficient global response to the challenges from climate change: ways need to be found both to prevent carbon leakage as mitigation measures in high-emitting countries cause emissions to shift there, and to exploit the relatively cheap opportunities for emissions reduction there. At least initially, emissions mitigation in low-income countries might be better promoted through climate finance (e.g., international offset programs and direct investments from climate funds).

As regards policy reform, low-income countries should focus on "getting energy prices right" from a local perspective, which would also have climate benefits. The first priority is to scale back any fossil fuel subsidies (especially consumer subsidies for high-carbon fuels). Although these subsidies are often rationalized on distributional grounds, such concerns are better addressed through more targeted policies (e.g., safety nets, investments in primary education), rather than artificially holding down energy prices (which benefits everyone, and often the rich more than the poor). The second priority is then to impose appropriate taxes on energy. Revenue considerations should involve integrating consumption of energy products under broader value-added tax systems. In fact, the case for taxation of energy is especially robust in developing economies, where problems of weak administration and tax compliance hinder the effectiveness of broader fiscal instruments. Further excise taxes on fuels are warranted to cover their potential local environmental damages (e.g., charges for the human health risks due to local pollution) and other side effects associated with fuel use (e.g., traffic congestion).

Lessons from Chapter 7: International Aviation and Maritime Charges Are a Promising Source of Climate Finance, although There Are Other Options

Pricing carbon for international aviation and maritime fuels is an appealing source of climate finance, as national governments do not have an obvious claim on the tax base. In addition, these fuels are currently under-taxed from both an environmental perspective and from a broader fiscal perspective (e.g., airline passenger tickets are exempt from value-added taxes), and they would be relatively straightforward to administer (e.g., on fuel distributors). The charges would need to be coordinated internationally to limit tax avoidance and competitiveness concerns. Compensation may be needed to secure the early participation of developing economies and to entice broader entry into the pricing agreement over time, but workable schemes should be feasible.

The case for carbon pricing and removal of fossil fuel subsidies is also strong. As already emphasized, carbon pricing should ideally form the centerpiece of mitigation efforts, and it could play a key role in catalyzing the private part of climate finance for developing economies (via emission offset programs). Removal of fossil fuel subsidies also provides mitigation benefits. These pricing reforms would yield substantial new revenues—potentially about US$250 billion a year for appropriately scaled carbon pricing in developed economies and US$40 to $60 billion a year from subsidy reform—though governments may be reluctant to hand over much domestic revenue for international purposes in the current fiscal environment.

Revenues can also be raised through broader fiscal instruments, though in this case costs are not offset by mitigation benefits. For personal income taxes, corporate income taxes, and value-added (or sales) taxes, the general recommendation is that exemptions and other tax preferences should be scaled back first, as this is usually a less distortionary way to raise revenue than increasing overall tax rates. Taxes on the financial sector are another possibility, though efficiency considerations favor taxing financial activities rather than (as usually proposed) financial transactions.

Lessons from Chapter 8: Carbon Pricing Programs Have Evolved over Time with Experience

Market-based mitigation policies implemented to date have performed reasonably well on effectiveness and cost-effectiveness grounds compared with regulatory approaches. Often, however, these gains have fallen somewhat short of their full potential, partly because actual designs have deviated from economically efficient designs, due in part to preferential treatments and exemptions (e.g., in Scandinavian countries, carbon tax rates vary considerably across end users). Market-based policies have also induced innovation in and adoption of emissions-reducing technologies (though again these gains are not always as large as expected). Carbon leakage effects to date have been relatively modest.

Emissions pricing programs often take the form of "hybrid" schemes that combine upstream and downstream elements and emissions taxes with emissions trading. For example, in Australia, large downstream emitters are covered under a cap-and-trade system, while more diffuse sources (e.g., home heating fuels and transportation fuels), are covered by taxes on fuel distributors. Although ideally these systems should transition to a single, comprehensive pricing instrument, they may perform reasonably well for the time being as they can still cover most energy-related CO_2 emissions. But provisions to limit price volatility for emissions trading systems may be required to harmonize, approximately, emissions prices across sectors (thereby promoting cost effectiveness).

Although the Kyoto Protocol sought to simultaneously control six GHGs by translating them into a common index of CO_2 equivalents, no existing program covers all these gases. For administrative ease, most programs focus solely on energy-related CO_2 emissions, though many programs are now beginning to transition to a more comprehensive coverage of gases as monitoring and verification capacity improves.

Price volatility has been a significant concern in trading systems to date (though experience is limited to developed economies). Cap-and-trade systems often limit price volatility through provisions for permit banking (allowing entities to save permits for later use when expected allowance prices are higher) and advance auctions (allowing entities to buy allowances at current prices for use in several years). Permit borrowing (which allows entities to use permits before their designated date) is more restricted, due to a fear that firms might default on owed allowances (though this does not seem to have been a problem). If these provisions work reasonably well, there is less need to transition to a carbon tax on price volatility grounds.

Revenues from carbon taxes and auctioned allowances have been used for reducing other taxes, compensating industries, offsetting regressive impacts on households, and promoting renewable and energy efficiency programs. Use of revenues for industry compensation has diminished over time, however, with greater appreciation of the value of forgone revenues and tendency to overcompensate (power producers reaped windfall profits in the early phases of the EU trading scheme due to free allowance allocations, but future ETS allowances will be largely auctioned). As we might recommend, some programs (e.g., in Australia) have addressed adverse effects on low-income households with progressive adjustments to the broader tax system.

Emissions "offset" provisions are a common means for reducing the cost of cap-and-trade programs. But the challenge is to ensure that the credited emissions reductions outside of the formal program can be measured and would not have occurred anyway (without the offset credit). Due to concerns about credibility, most programs impose limits on offsets, but newer approaches attempt to distinguish between more credible offsets (which are allowed) and less credible ones (which are rejected). Under a carbon tax, offsets are not needed to contain the emissions price, but if they are not used, untaxed sectors are left completely without control. In either system, offsets can be introduced over time (e.g., to promote financial flows to developing economies) as verification techniques improve.

The Role of Finance Ministries

To date, environmental ministries have been most involved in climate change discussions. A final lesson is that finance ministries need to be more actively involved in carbon pricing policy, given the significant amount of revenues at stake and that these instruments are a natural extension of existing fuel excise tax systems.

References and Suggested Readings

For further discussion on the design of climate mitigation policies, see the following:

Aldy, Joseph, Alan J. Krupnick, Richard G. Newell, Ian W. H. Parry, and William A. Pizer, 2010, "Designing Climate Mitigation Policy," *Journal of Economic Literature,* Vol. 48, pp. 903–34.

Nordhaus, William D., 2008, *A Question of Balance: Weighing the Options on Global Warming Policies* (New Haven, Connecticut: Yale University Press).

Stern, Nicholas, 2007, *The Economics of Climate Change: The Stern Review* (Cambridge, UK: Cambridge University Press).

For more details on the science of global warming, see:

IPCC, 2007. *Climate Change 2007*: *The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (New York: Cambridge University Press).