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How to Design a Carbon Tax

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How to Design a Carbon Tax

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Key Messages

- Market-based instruments like carbon taxes are potentially the most effective policies for reducing energy-related CO_2 emissions. They do this by cutting the demand for fossil fuels and making it more attractive to use zero-carbon fuels like renewables.

- Ideally, taxes should be applied where fossil fuels enter the economy with rates levied in proportion to carbon content and refunds for any downstream carbon sequestration.

- To keep down overall policy costs, carbon tax revenues should be used to alleviate distortions created by the broader fiscal system, reduce government debt, and/or fund valuable government expenditures. Revenues might also fund climate adaptation (e.g., water defenses) where private sector investment would otherwise be too low. Care should be taken not to use valuable revenue for inefficient subsidies (e.g., fuel subsidies).

- Cutting pre-existing, environmentally blunt, energy taxes (e.g., excises on electricity or on vehicle ownership) may help to compensate adversely affected groups for higher energy prices, thereby enhancing feasibility. Alternatively, low-income groups and firms in trade-exposed sectors might be compensated through targeted measures such as adjustments to the broader tax/benefit system and transitory production subsidies.

- Non-CO_2 GHGs might be covered directly under the tax, or indirectly through emissions offset credits, as capability for monitoring and verification is developed over time.

- Carbon pricing policies are the most important instruments for promoting the development and deployment of clean technologies. Supplementary instruments may be needed to help overcome market barriers to large clean-energy investments, though they need to be carefully designed.

- At an international level, a carbon tax floor negotiated among major emitters is a potentially promising way forward (and could be easier to negotiate than multiple country-level emissions targets).

[1] This policy note has benefited from the constructive comments of Joseph Aldy, Terry Dinan, Daniel Hall, Michael Keen, Richard Morgenstern, and Vicki Perry.

1. Objectives of the Carbon Tax

Carbon pricing policies are potentially the best instruments for incorporating environmental damages into the market price of intermediate inputs and the price of final goods and services. By reducing the demand for fossil fuels and discouraging exploration for new fossil fuel reserves—especially fuels with high CO_2 content—these pricing effects exploit the entire range of behavioral changes at the household and firm level for reducing energy-related CO_2 emissions. Carbon pricing also creates across-the-board incentives for the development and deployment of clean-energy technologies, and boosts the supply of carbon-free renewable substitutes. A carefully designed time path for carbon pricing not only ensures that firms and households use less CO_2-intensive production methods, appliances, vehicles, machines, etc. but also that renewables are brought to the market and phased in more quickly. Especially attractive in the present fiscal crisis, carbon pricing can also provide a substantial source of government revenue. Here the focus is on carbon taxes, though as explained in Chapter 1 (revenue-raising) emissions trading systems are also very promising approaches.

In crafting carbon tax legislation, policymakers may be concerned about a number of design issues such as:

- the choice of the tax base
- how tax revenues might be used
- what might be done to address concerns about distributional effects and competiveness
- how to simplify administration and compliance
- to what extent non-energy-related emissions and emission offsets might be integrated
- whether supplementary instruments are needed to promote clean technology investments
- and how, at an international level, a carbon tax agreement might be negotiated and monitored

This policy note discusses these issues in turn. Other important questions, such as the appropriate level and time path of carbon taxes, the pros and cons of taxes versus other emissions control instruments, appropriate policies for low-income countries, and complementary reform of energy subsidies, are discussed elsewhere in this volume. At the end of the paper, we briefly evaluate some existing tax systems in light of our recommendations.

2. Choice of Tax Base

The most important consideration in choosing the base of a carbon tax is to maximize the coverage of emissions sources (thereby avoiding implicit or explicit exemptions to significantly polluting activities), though beyond some point further extensions to the tax base may not justify the additional administrative and compliance complexities. All potential CO_2 emissions across different fuel types and fuel users should be taxed at the same rate, as they all cause the same environmental damage, regardless of how they are generated or in which location.[2]

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[2] There could be special cases where exemptions are warranted on economic grounds, though these cases need to be carefully evaluated. One possibility is that excise taxes on transportation fuels are already excessive (prior to further tax increases from carbon charges) in that they may 'overcorrect' for other problems like road congestion, accidents,

Ideal tax base. Ideally, carbon taxes should be levied upstream in the fuel supply chain to maximize coverage while also limiting (for administrative reasons) the number of collection points (see later). And charges should be levied in proportion to the fuel's carbon content to equate prices across (potential) emissions releases.[3] Refunds should be provided to encourage downstream carbon capture and storage (e.g., at coal-fired power plants), if and when these technologies become viable.[4]

Uniform charging for carbon alters absolute and relative energy prices, providing firms and households with incentives to exploit all of the major opportunities for reducing fossil fuel CO_2 emissions. These opportunities include reducing electricity demand, improving power plant efficiency (i.e., reducing fuel inputs required per kWh of generation), and shifting from generation fuels with high carbon intensity (coal) to fuels with intermediate carbon intensity (fuel oil, natural gas) and from these fuels to zero carbon fuels (nuclear, hydro and other renewables). They also include reducing the demand for electricity, transportation fuels, and direct fuel use in homes and industry through improving the efficiency of energy-using products (e.g., vehicles, lighting, household appliances) and reducing the use of these products (e.g., reducing km driven per vehicle, economizing on the use of air conditioners). A uniform price on CO_2 provides the same incentive at the margin to reduce emissions across all these possibilities, since everybody gets the same savings for altering behavior in ways that reduce emissions by an extra ton.

Table 1 illustrates (retrospectively for 2009) the potential impact of a $22 per ton (€16) CO_2 charge on various energy prices in selected countries, assuming full pass through of the tax into prices (which should be a reasonable approximation over the longer run for individual countries).[5] In proportional terms, the greatest impact is on coal prices, which rise by 45-200 percent across the countries. Retail gasoline prices, in contrast, rise by 3-9 percent, and residential natural gas prices by 3-12 percent—gas price increases for generators and industry tend to rise more in relative terms as they pay lower prices (e.g., due to bulk buying). The estimated impact on residential electricity prices varies between 1 percent (in France where generation is largely nuclear) to 28 percent (in Indonesia, where electricity is heavily subsidized)—again, relative price increases are larger for industry.

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and local tailpipe emissions, though these problems typically warrant fairly high fuel taxes (see e.g., Parry et al. 2007).

[3] For example, combusting a liter of fuel oil or diesel produces about 0.0027 tons of CO_2; a liter of gasoline produces about 0.0023 tons; and combusting a (short) ton of coal produces about 2.45 tons of CO_2 (see http://bioenergy.ornl.gov/papers/misc/energy_conv.html). To convert CO_2 to carbon emissions, divide by 3.67.

[4] The refund should equal the CO_2 tax times the quantity of CO_2 that is captured and permanently stored. The tax paid on the carbon content of fossil fuel acts like a deposit which is then refunded if the carbon is captured and stored.

[5] For fossil fuels the absolute price increase—the CO_2 content of the fuel in tons times $22—is taken to be uniform across countries, while the percent price increase varies due to differences in prior fuel prices across countries. For electricity, the absolute price increase also varies across countries, depending on their generation mix, which determines CO_2 per kWh.

Other (less efficient) tax bases. Downstream systems taxing emissions released from major stationary sources (e.g., coal and natural gas plants, metal manufacturers) may be a more natural extension of earlier local pollution programs and they encompass the lowest-cost abatement opportunities (which are usually in the power sector).

However, downstream programs tend to exempt entities with emissions below a certain threshold and they need to be accompanied by additional programs to cover transportation and home heating fuels. In the European Union, the Emissions Trading System (ETS) has a downstream focus and misses out on about 50 percent of energy-related CO_2 emissions. Although an EU wide carbon tax on fuels currently exempt from the ETS has been proposed, better still would be one upstream program applying a uniform carbon price to all fossil fuels.[6]

Excise taxes on electricity use are common among OECD countries (though they are more significant at the residential than industrial level). They are often justified on climate grounds, but they are far less effective at exploiting emission reduction opportunities than comprehensive carbon taxes. Electricity taxes provide no reward for switching to cleaner generation fuels, improving power plant efficiency, or reducing emissions outside the power sector. Within the power sector, coal taxes are somewhat better, as they encourage shifting away from high-carbon generation fuels, though they still fail to encourage shifting from natural gas and fuel oil to zero-carbon fuels.[7]

Vehicle ownership taxes (e.g., excise taxes, registration fees, annual road taxes) are especially common. Even within the transportation sector however, these taxes do not (in general) encourage households with vehicles to drive less. And, depending on their design, they may provide little or no incentive for improving new vehicle fuel economy.[8] Again, any climate-policy rationale for these taxes is removed with appropriate pricing of CO_2.

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[6] It is sometimes suggested that a downstream tax will have greater effect as it is more visible than an upstream tax. However, in an upstream system firms are likely to pass forward the embedded carbon tax in higher prices for coal, gasoline, and other fuels, so power generators, motorists, and so on, would be fully aware of the fuel price increase.

[7] For residential electricity taxes, it is important to recognize the distinction between excise taxes and value-added taxes. Typically, residential electricity consumption is included in the base of a general value added (or sales) tax. This is entirely appropriate, as consumption of all household goods and services should be included in these taxes to avoid distorting the choice among different consumer products. Excise taxes, on the other hand, apply only to electricity, and therefore raise the price of electricity *relative* to other final goods. This is generally undesirable when more effective instruments for reducing emissions (i.e., carbon taxes) are available (though see Chapter 6 for further discussion of this in the context of low-income countries).

[8] A recent trend has been to vary vehicle ownership taxes with engine size classes, or emission rates per mile. Although these tax systems provide some incentives for fuel economy improvements, they are not cost-effective. They tend to place too much of the burden of emissions reductions on shifting people into vehicles that are just below a higher tax bracket, and too little on other opportunities, like improving the fuel economy of vehicles that are a long way from the next, lower tax bracket. And they distort people's choices over different vehicles by causing a bunch of demand for vehicles classified just below the next (higher) tax bracket.

3. Revenue Use

Carbon taxes can provide a substantial new revenue source, which is especially valuable in times of fiscal consolidation. Revenues under an appropriately scaled carbon tax—around $25 per ton of CO_2 (see Chapters 3 and 4)—would amount to around 1 percent of GDP for many countries (and even more for fossil fuel intensive economies like China, India, and Eastern Europe). As a rough rule of thumb, up to 5 percent of this revenue might be required to administer the carbon tax. How should the rest of the revenue be used?

Earmarking of *all* tax revenues for environmental programs (e.g., subsidies for clean technologies, climate finance, R&D, or compensation for industry) is not generally desirable. The amount of revenue raised from a carbon tax has nothing to do with the socially desirable amount of spending on environmental programs. Instead, these programs need to be justified in their own right, by additional market failures (see below): that is, they need to generate economic benefits comparable to those from alternative revenue uses.

The simplest way to use revenues to boost economic efficiency is to finance reductions in other taxes that distort the broader economy. For example, income, payroll, and general consumption taxes tend to (moderately) reduce labor force participation, effort on the job, and shift production towards the informal sector. This is because they reduce the real returns to formal work effort (i.e., the amount of goods that can be purchased with earnings from a given amount of work hours). Similarly, taxes paid by firms on the return to capital investments, and taxes paid by households on dividend income and capital gains, tend to reduce capital accumulation below levels that would be economically efficient. Using carbon tax revenues to reduce these broader tax distortions produces economic benefits by improving incentives for (formal) work effort and capital accumulation. It also helps to 'lock in' in the carbon tax, as a future government that wished to abandon the tax would presumably have to impose other (politically difficult) tax increases elsewhere to make up for lost revenue.

Offsetting this revenue-recycling benefit however, is the adverse effect on economy-wide employment and investment as overall economic activity contracts (slightly) with the impact of carbon taxes on energy prices and production costs. In fact, despite the potential for revenue recycling, the overall costs of carbon taxes are typically positive, though fairly small—about 0.03 percent of GDP for the average developed country in 2020 for the scale of carbon price considered here.[9] Carbon taxes therefore still need to be justified on environmental grounds: roughly speaking, an efficient tax system would charge CO_2 emissions for environmental damages, and meet the government's remaining revenue requirements, mostly through broader fiscal instruments.

Carbon tax revenues might also be used for deficit reduction. Again, this use of revenues implies a significant economic benefit if it avoids the need for (near term or more distant) increases in other distortionary taxes, or helps to avoid economic crises. Revenues could also

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[9] With revenues used efficiently, an (albeit rough) estimate of the annual economic costs of a carbon tax is given by one-half times the CO_2 tax times the emissions reduction. Suppose (from IMF 2011) a $25 per ton CO_2 tax reduces OECD emissions are by 10 percent from a base of 11billion tones, then the approximate cost of the policy would be $13.8 billion. Dividing by projected OECD GDP of $49.5 trillion (IMF 2011), gives the above figure.

finance socially desirable public spending—in fact, the returns to public investments in education, infrastructure, health etc. in developing countries can be especially high, if they suffer from capital scarcity (e.g., Collier et al. 2009). Revenues could also be used domestically for adaptation if the private sector would otherwise under-invest in these activities (e.g., defenses against higher sea levels would likely be inadequate without public support) or internationally for climate finance (see Chapter 7).

But the key point here is that revenues need to be used productively to keep down the overall costs of carbon taxes. If revenues are not used productively, for example they are not used to lower tax rates to boost work effort, or worse, they are used for socially wasteful spending, this can greatly increase the overall cost of the policy to the economy. This is important to bear in mind if policymakers are considering using some of the revenues for compensation schemes (see below).

Nonetheless, there is a tension between environmental and fiscal objectives. The more effective a given carbon tax in reducing emissions, the more the tax base is eroded, and the less revenue it will raise. On the other hand, even if the carbon tax is less successful in reducing emissions, the case for the tax may still be robust, as it provides a low-cost, relatively non-distorting way to raise public revenue.

4. Addressing Distributional Burdens and Industrial Competitiveness

The higher energy prices caused by carbon taxes are desirable to reduce emissions and promote clean technology investments. At the same time however, they can have unpalatable implications for distributional incidence and industrial competitiveness, which can hold up the introduction of carbon taxes.

Distributional incidence. Given that—at least in middle- and high-income countries—spending on fuels and electricity tends to decline as a share of income as households become wealthier, poorer households tend to have the highest budget shares for energy, making them more vulnerable to higher energy prices.[10] In low-income countries, wealthier groups may be the most vulnerable, as the fraction of households owning vehicles or with access to the power grid may be much higher for them than for poor households (see Chapter 6) though wealthy groups are often politically powerful and successful in resisting energy taxes or securing exemptions from these taxes. In short, carbon taxes often run counter to distributional objectives, and in practice their design may be subject to the constraint that they do not worsen income inequalities.

Competitiveness. Higher energy prices may also harm the competitiveness of energy-intensive firms in trade-sensitive sectors where it is difficult to pass forward higher input costs into final

[10] One US study finds, for example, that the burden of a carbon tax on the bottom income decile is 3.7 percent of annual income, whilst it is a mere 0.8 percent of income for the top income decile (e.g., Hassett et al. 2009). The differential burden borne by low income households may become less pronounced over time however, as some of the burden of the carbon tax is shifted to owners of capital and of fossil fuels. And not all people with low income in a given year, who include, for example, college students, should be viewed as poor.

product prices. Moreover, reduced production at home by these firms may cause increased production in other countries causing emissions leakage (i.e., emission increases in other countries that offset some of the emissions reductions at home).

Responses. How might these problems be addressed? Artificially holding down energy prices (below levels warranted on environmental grounds) is not a good response, as most of the benefits leak away to other households and firms, rather than the target groups.

One way to alleviate concerns about incidence and competitiveness, and circumvent the pressure for border adjustments, is to scale back pre-existing, environmentally ineffective energy taxes. In many OECD countries, the impacts of carbon taxes on electricity prices could, at least in part, be offset by lowering pre-existing excise taxes on electricity use at the household level and in some cases at the industry level (IMF 2011). In fact, with pricing of both carbon and local air pollution in place, excise taxes on electricity become redundant (from an environmental prespective). Similarly, in many countries the added burden of carbon pricing on motorists can be approximately offset by lowering vehicle ownership taxes (IMF 2011).

Another approach is to alter the broader tax/benefit system, using some of the carbon tax revenue, to approximately compensate target groups. In countries where low-income households pay either income taxes or payroll taxes, increasing the threshold income level below which no tax is paid provides a bigger rebate (relative to income) for these households compared with wealthier households (see the discussion of Australia's carbon pricing scheme in Chapter 8).[11] Moreover, cutting the average rate of income/payroll tax still has some favorable effects on work incentives. In countries where many households do not pay direct taxes, a possibility might be to use a portion of carbon tax revenue to finance a transfer to low-income households, and the rest to finance a general reduction in consumption taxes. For vulnerable firms, transitory subsidies for production, or adoption of energy-saving technologies, might be provided to roughly offset the harmful effect of higher energy prices on competitiveness.

The danger of these compensation schemes, however, is that they can sacrifice some of the potential economic benefits from recycling carbon tax revenues. Transfer payments to low-income households, for example, do not improve work incentives. For the greatest economic efficiency, compensation would be kept to the minimum needed to offset the adverse distributional effects of carbon taxes for the target groups and, insofar as possible, would take the form of tax cuts that alleviate broader distortions in the economy.

In principle, complementing a carbon tax with a well-designed and well-implemented system of border tax adjustments could be an effective way to deal with competitiveness and leakage issues. And border tax adjustments encourage other countries to participate in pricing regimes (as these countries are penalized for not joining).

Assuming border adjustments reflect genuine economic concerns rather than protectionist pressures from domestic interests, there are two practical implementation challenges. First, these

[11] If people receive payments under an earned income tax credit scheme, heating supplements, and so on, the threshold could be the level of income above which no payments are received.

adjustments could quickly become administratively complex if they are applied to many products, and if rates are differentiated according to the carbon intensity of the exporting country. However, it makes sense to concentrate the adjustments on industries where competitiveness concerns are especially acute—mainly intermediate products like chemicals and plastics, primary metals (e.g., steel, aluminum), and petroleum refining. The second problem is that these adjustments might possibly (depending on how they are interpreted), run afoul of free trade agreements, in which case they may need to be designed somewhat differently (and less efficiently).

Yet another possibility, if a carbon tax is infeasible for the present, and which limits harmful impacts on vulnerable firms and households, is to use a series of tax-subsidy policies, known as 'feebates'. Chapter 1 explains how these policies work and how they might be applied to lower average CO_2 per kilowatt-hour (kWh) from power generation and improve the energy efficiency of vehicles, appliances, energy-using machines, etc. Policymakers are free to choose 'pivot points' for emissions intensity or energy consumption rates above/below which firms pay fees/receive rebates: a higher pivot point implies a smaller impact of the policy on energy prices (which may help with acceptability), though it also implies less revenue will be raised (as a greater portion of firms receive rebates rather than pay fees).

From an environmental perspective, the drawback of feebates is that, unlike a carbon tax, they provide weaker incentives for conservation downstream from where the feebate is applied—for example, they do not encourage people to drive less and may provide little incentive to conserve on use of electricity-using products. Moreover, they cannot be implemented all the way upstream (e.g., on refineries), which raises administrative and compliance costs (see below). Nonetheless, feebates offer a reasonably effective and cost effective way to exploit many (though not all) of the opportunities for reducing emissions that would be forthcoming under carbon taxes, while largely avoiding the need for compensating households or trade sensitive sectors.

Finally, none of the above responses alleviates the burden of carbon taxes on upstream fuel suppliers, particularly domestic coal industries. Even though the tax on coal may be mostly passed forward in higher prices, the industry will still contract, leading to a loss of profits and employment, and political pressure not to properly price coal. In fact (in the absence of widespread development and deployment of CCS technologies) a key purpose of a carbon tax is to promote a substantial shift away from coal. For this case, assistance might instead take the form of worker re-training and job relocation programs (this would likely absorb only a minor fraction of the carbon tax revenues).

5. Administrative and Compliance Considerations

The choice of collection points for the carbon tax should aim to maximize emissions coverage, whilst minimizing administrative and compliance costs, as well as the risks that people and firms will evade paying the statutory taxes. In the latter regard, the tax should usually be imposed where the number of covered entities is smallest—most obviously, administrative and compliance costs are lower for upstream systems than downstream systems.[12]

Even under an upstream approach, there are a range of options.

As regards oil, in countries like the United States there are far fewer petroleum refineries than oil wells, implying that the tax should be easier to collect at the refinery level. The (small) amount of oil used to make tar (which does not release emissions because it is not combusted) can easily be exempt from a refinery-level tax.

Natural gas is used mostly for heating residences and industry and for producing electrical power. Most natural gas comes from stand-alone gas wells and a small amount is released from coal beds. Again, taking the United States as an example, it would make administrative sense to collect the carbon from approximately 500 of the largest operators—which would cover almost all of reserves and production—rather than from the approximately 450,000 natural gas wells. A reasonable alternative to taxing the operators is to tax the processing plants plus the small amount of gas put into the pipeline system without processing.

As for coal, it is probably best to tax at the production level (mine mouth) rather than at the consumption level (electric utilities and industry) to limit collection points. In principle the tax should vary moderately by coal type according to carbon content (anthracite, bituminous, sub-bituminous and lignite emit 103.6, 93.5, 97.1 and 96.4 kg of CO_2 per million Btu respectively), though administration may be easier without this differentiation.[13]

There should also be charges on carbon content at the seaports, for the maritime contribution to refined oil products, natural gas, and coal.[14] Export taxes would be appropriate if domestic supplies are exported to regions that do not already price carbon.

In fact, for many developing countries, administering carbon taxes, which basically just requires monitoring fossil fuel supply, may be much easier than administering broader taxes, strengthening the case for their inclusion as part of the broader fiscal system. For example, receipts from the personal income tax in developing countries tend to be low, reflecting the relatively large informal sector and tax evasion/avoidance opportunities for the wealthy.

6. Broader Coverage Issues

Energy-related CO_2 emissions account for around 80 percent of GHG emissions in developed countries (in CO_2 equivalents) and a somewhat smaller share in developing countries

[12] For example, in the United States or European Union an upstream policy would apply to approximately 2,000 entities compared with about 12,000 entities in downstream program.

[13] Cap-and-trade schemes often delegate the decision of what carbon contents to reckon for different grades of coal to a relevant agency and the same agency could also do this for the carbon tax.

[14] This is not a problem because the number of seaports for each of these fuels is limited, and becoming increasingly more limited due to the greater size of oil, gas, and coal-transporting vessels, which necessitates deepwater facilities.

(where emissions from agriculture and deforestation are greater). Once CO_2 pricing is established, it makes sense to progressively expand the tax system to integrate other emissions sources, as institutional capability for reliable monitoring and verification is developed over time. The most urgent source of extensions (to the 'low-hanging fruit' where potential emissions reductions are significant and reduction costs per ton relatively low) will vary by country: for some developing countries, sustaining forests may be the top priority.

Non-CO_2 GHGs, mostly methane, but also nitrous oxide, fluorinated gases and sulfur hexafluoride, are relatively cheap to avert. Some of these sources would be fairly straightforward to include under a formal GHG tax, such as vented methane from underground coalmines and landfills.

Other sources could be incorporated through offset programs, where the onus is on the individual entity to demonstrate valid reductions (e.g., capture of methane from livestock waste in airtight tanks or covered lagoons). Under a tax regime the primary effect of offset provisions is to reduce overall emissions (for a given emissions price), while under an emissions trading program the primary effect is to lower allowance prices in the cap (without affecting total emissions). Offsets are effectively a subsidy to a polluting industry, however, and they need to be carefully designed to avoid the risk of encouraging more production from that industry.

In a few cases, emissions can be difficult to integrate under the carbon tax. Examples include methane from surface mines (emissions are difficult to capture as they are released as the overburden is removed) and fluorinated gas emissions due to leakage from, or inappropriate disposal of, vehicle air conditioners.

Domestic carbon sequestration projects (reducing deforestation, reforesting abandoned cropland and harvested timberland, etc.) can also be integrated into domestic tax carbon regimes through emissions offset provisions.[15] But assessing the true carbon benefits of such projects can be quite challenging (see Chapter 5). Moreover, sequestered carbon in trees is not necessarily permanent if trees are later cut down, decay or burn, which requires assignment of liability to either the offset buyer or seller for the lost carbon. And forest conservation in one country could lead to increased land clearance and emissions elsewhere, for example through upward pressure on global timber prices. Thus, while studies suggest that forest sequestration is often a low-cost option for reducing CO_2, policymakers should proceed cautiously with the integration of this sector, to avoid undermining both the effectiveness and credibility of the tax regime.

Fossil fuel suppliers could be allowed to obtain tax credits by purchasing emission offset projects in developing countries, for example, through the CDM (this is common in cap-and-trade regimes to date, but less so under carbon tax regimes). Again, it can be challenging to verify whether a project (e.g., a solar energy plant) would have gone ahead anyway without the offset (especially when the offset payment is small relative to plant construction costs). Although

[15] In this context, an offset is a reduction in emissions from a sequestration project that that can be purchased by entities formally covered by a carbon tax, in return for a corresponding reduction in their tax liability. The offset program might be limited to major landowners (e.g., the major paper and forest product companies) to limit administrative costs.

international offset programs are a potentially attractive way to channel funds for clean technologies to developing countries, again they should be integrated progressively under carbon tax regimes, as the credibility of offset programs is established (it is not clear that the capacity of the CDM is large enough at present however to take on these extra duties).

7. Are technology policies needed to complement a carbon tax?

The ultimate objective is to switch from using conventional fossil fuels to phasing in more and more carbon-free fuels (solar, wind, nuclear, geo-thermal, coal with CCS, etc.), along with more efficient use of energy, and perhaps leaving a much greater part of coal, oil, gas, tar sands and shale gas reserves unexploited. If things are left to the market without any price on carbon emissions, zero-carbon fuels will be phased in too late. Establishing a credible future path for carbon pricing is the single most important policy for encouraging the needed technology investments. As discussed in Chapters 3 and 4, the standard recommendation is that this carbon price should ramp up progressively over time, at around 2-5 percent a year in real terms.[16] However, even an appropriate time profile for a carbon tax may not be sufficient to engineer the changeover to low-carbon technologies if market impediments hinder their development (see below).

However, there is some debate about whether carbon taxes should immediately be set at a very high level upfront to redirect technical change and rapidly reduce the emissions intensity of the energy system (e.g., Aghion et al. 2009, van der Ploeg and Withagen 2012).[17] In principle, even if policymakers wished to kick start green innovation, it would be better to target technological opportunities with specific additional incentives, rather than providing equal, across-the-board incentives for all emission reduction opportunities (regardless of the market impediments to individual technologies). Nonetheless, it can be challenging to design supplementary technology policies (in which case higher taxes can have some role in promoting more innovation).

These challenges include (among others discussed below) the difficulty of picking 'winners', the possibility that subsidies will be captured by lobbies for yesterday's technologies, and the possibility that very long-range benefits might be foregone if policymakers are overly focused on near-term innovation subsidies (at the expense of providing a credible long-term carbon price). Nonetheless, to the extent these challenges can be overcome, technology policies have an important role to play in complementing carbon taxes, as they can be targeted to where the source of additional market failures (i.e., under-investments in clean technologies) are most severe. To better understand these issues we distinguish private R&D from technology deployment (basic energy research funded by governments is also important, though it is difficult to make general policy recommendations in this case).

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[16] Eventually, the efficient carbon tax path may flatten as the cost of extracting conventional fossil fuels rises over time as they become depleted.

[17] Some have argued that stiff taxes are also warranted because, on ethical grounds, climate change damages to future (unborn) generations should be discounted at rates below market rates, implying that the present value of future climate damages is much higher (see Chapter 4).

Private (green) R&D. Even with a carbon tax in place, most likely research conducted by private firms into clean technologies would be inadequate.

Most importantly, innovators cannot appropriate all of the spillover benefits to other firms that might copy a new technology or use information embodied in the technology to further their own research programs. Although this problem applies to private sector R&D in general (justifying broad-based policies to encourage all R&D), the problem may be more severe for CO_2-reducing technologies where, due to uncertainty over future government's commitment to climate policy, innovators are unsure about longer-term demand for clean climate technologies. 'Network externalities' can represent a further impediment to the market implementing technologies like CCS where construction of pipeline infrastructure to transport captured CO_2 to storage sites can benefit other firms. Although stimulating energy-related R&D may crowd out socially productive R&D elsewhere in the economy, as scientists and engineers are diverted from other sectors, full crowding out seems unlikely.

It is not entirely clear which type of technology instrument should be used. As already noted, it may be politically difficult to efficiently allocate large upfront subsidies for R&D across different technological opportunities. Strengthening patent protection (by increasing their duration or defining them more broadly) is another possibility, especially if the private sector knows more about the potential for diffusing new technologies than the government. Green technology/innovation prizes could also play a role when imitation around patents is still easy, though this requires that governments have some sense of the potential market for the technology. Another possibility is for the government to pay the original innovator a fee each time the new technology is adopted by another firm (with the fee corresponding to the value of estimated emissions reductions from the technology), though if the technology is improved later by other firms, it is not clear which firm should receive future adoption subsidies.

In short, while targeted incentives for private R&D into clean energy technologies are a potentially valuable complement to carbon taxes, their design needs to be carefully assessed and the appropriate instrument may be different for different types of technologies. Higher initial carbon taxes are a further option if the need for redirecting technical change from CO_2-intensive to carbon-free modes of production is strong.

Technology deployment. Even if, after a new technology has been brought to market, there is a further set of impediments that may prevent full (socially efficient) diffusion of the technology, though analysts continue to debate the seriousness of these impediments. For example, households may be unaware of the lifetime energy savings from more energy efficient vehicles or appliances, and firms experimenting with a new type of technology may fail to capture the benefits from their 'learning-by-doing' to other firms adopting the technology later on.

There is a potentially important role for informational campaigns here: if the problem is that consumers are unaware of potential energy savings, governments can provide information (through advertising, for example) to address that problem. There may also be a role for additional policy instruments to push the market penetration of specific new technologies, but again these instruments need to be carefully designed. One issue is that future net benefits of new technologies are uncertain—there is a downside risk that their costs may turn out to be higher than expected relative to alternative technologies, perhaps because of changes in fuel prices or prices of materials needed to manufacture the technology. Pricing instruments (like feebates, or technology adoption subsidies) are better able to handle this uncertainty than regulatory approaches that force market penetration regardless of future costs—under pricing approaches, the technology will not be adopted if costs are excessive, despite the policy incentive.

Another issue is that deployment policies should be transitory and phased out as the technology matures and becomes widely used (despite opposition from lobbies that may have been built up to keep them). Ideally, this phaseout would be announced upfront and could be a function of time (e.g., the policy lasts 15 years, regardless of how much deployment occurs) or of market performance (e.g., the policy ratchets down whenever penetration goals are met), or some combination of the two.

8. International Issues

Top-down approaches. So far, countries have negotiated over country-level emissions targets and over side payments. The big CO_2 emitters in the past have been the developed countries, but in the next few decades emerging economies (e.g., Brazil, Russia, India, China) are likely to be responsible for an increasing share of global emissions. A credible and effective coalition for mitigating climate change must include at least the main emerging and populous economies of China and India.

Negotiations over country-level emission targets are often contentious, not least because countries may have generous provisions for questionable emissions offsets that may effectively relax their target. Furthermore, updating emissions quotas over time is challenging, as baseline emissions of CO_2 in the absence of an effective climate policy grow at different rates across countries.

It might be a little less challenging to reach an international agreement over a common CO_2 price (and the annual rate of growth in that price) than over numerous country level quotas. Prospects for agreement might be enhanced further if the tax took the form of a carbon tax floor. Such a floor is attractive in that it provides some protection for countries willing to set relatively high carbon taxes, and it reduces downside risks to clean technology innovation.[18]

A possible objection is that countries may undermine the floor through 'fiscal cushioning' (use of broader energy tax/subsidy provisions to undermine the effectiveness of the formal CO_2 tax) or manipulation of other policies (e.g., avoiding significant regulation of local air pollution from coal-burning plants or charging far-below-market royalties for fossil fuel extraction on public lands). This is a potentially major problem, but it should not be overstated. These other provisions are typically very blunt at targeting emissions compared with a well-designed carbon tax, and therefore have only limited impacts on offsetting the CO_2 emissions reductions from the tax. Nonetheless, a global carbon tax agreement would need to include provisions (e.g., monitoring by an international body) to address potential attempts at cushioning.

[18] A useful precedent may be the minimum level of excise taxes and VAT rates agreed upon in the European Union.

Another possible objection to carbon tax agreements is that countries forgo controls over annual emissions targets. Offsetting this argument is that future climate change is driven by historical atmospheric GHG accumulations over many decades, rather than emissions in any one given year. Nonetheless, a possible compromise (if policymakers wish to retain some direct control over emissions) might be to combine carbon tax floors with 'carbon budgets'. This would leave countries with flexibility over their annual emissions (subject to imposing the tax floor) but their cumulated emissions over, say, a ten-year period, could not exceed a maximum allowable amount (requiring increases in their carbon tax if they are not on track to stay within the carbon budget).

Bottom-up Approaches. In the absence of a formal international agreement, individual countries might initiate their own pricing programs, which subsequently might be harmonized with those in other countries. It is sometimes argued that permit trading schemes are better for promoting a 'bandwagon effect' to ultimately bring countries together in an international climate agreement, given mutual gains from trading permits at harmonized prices. However, carbon taxes might provide a similar bandwagon effect, if they include border tax adjustments for imports from nations that have not already implemented pricing policies. When a new country joins the carbon tax agreement it then gets to keep the tax revenue on its exports that previously accrued to governments of other countries already in the agreement that were imposing border adjustments on those exports.

International Aviation and Maritime Emissions. Chapter 7 discusses the strong environmental and fiscal case for, and potential implementation of, charges on CO_2 for international aviation and maritime emissions. International coordination here is especially important due to the mobility of the tax base—for example, in shipping it is generally easy to re-fuel in ports that do not levy fuel charges. And there is currently much interest in international transportation fuel charges as a source of revenue for climate finance. If an international agreement over these charging schemes could be reached in the next few years, including acceptable compensation schemes for developing countries, this would set a valuable precedent for the (far more challenging) task of developing a comprehensive CO_2 pricing agreement.

9. Examples of Operational Carbon Taxes

Several countries or regions already have carbon taxes in place (Chapter 8 provides an in-depth discussion of experience with emissions pricing policies more generally).

Often (as recommended above) these taxes have been implemented in a revenue neutral fashion, that is, other taxes were reduced when the carbon tax was introduced. For example, a large portion of the revenues from carbon pricing in Australia will finance a substantial increase in personal income tax thresholds.

And in some cases the scale of the tax seems entirely reasonable based on discussions in Chapters 3 and 4. Australia is again a good model as the emissions price this year will be equivalent to about US $25 per tonne of CO_2 (though the policy is an emissions trading program that will later allow more volatility in emissions prices). And in 2008, British Columbia implemented a revenue-neutral carbon tax of US $10.4 per ton of CO_2 that has since risen progressively to about $30 per tonne.

Nonetheless, there are some significant differences in carbon tax rates across countries, suggesting potential for gains in trade (e.g., better harmonization of tax rates across countries or allowing entities in higher price regimes to purchase emissions reduction credits from countries with lower prices). Even within Europe, for example, Denmark has implemented since 2005 a pricing scheme on fossil fuel emissions corresponding to US $114 (80 Euro) per tonne of CO_2, Norway has since 1991 a CO_2 tax on fossil fuels (on top of the excise taxes on fuels) amounting to US $21 per tonne of CO_2, while Sweden has implemented in 1991 its carbon energy tax amounting to US $126 per tonne of CO_2. China is planning a modest tax equivalent to US $3 per tonne of CO_2, rising to US $8 per tonne on heavy industry for 2012, initially starting with several pilot cities.

Moreover for various reasons—particularly exemptions and tax preferences in response to concerns about equity and competitiveness, and the use of multiple, overlapping, tax instruments—often there is considerable disparity in emission prices across fuel types and fuel users, even within a country (see, for example, discussions in Sumner et al. 2011 and Heine et al. 2012). Whether there is a strong case for levelizing tax rates depends however, on whether fuel types/users subject to taxes markedly different from the average are responsible for a significant share of emissions.

10. Conclusion

Carbon taxes are especially timely. Their widespread implementation would jump start the (long overdue) need to begin comprehensively controlling and scaling back global GHGs, while providing across-the-board incentives for developing clean technologies ultimately needed to stabilize the global climate system. At the same time, they provide a valuable revenue source for cash-strapped governments. In principle, carbon taxes are pretty straightforward to design and administer. Ideally they would be proportional to the carbon content of fuels and generally imposed upstream in the fossil fuel supply chain, for example, as a natural extension of existing tax systems for motor fuels.

One argument against carbon taxes is that the revenues might be squandered (or worse, used to fund socially unproductive spending). However, while the revenue use provisions in legislation accompanying the tax cannot be predicted in advance, it seems less likely that revenues would be wasted in today's fiscal climate, given that many governments are imposing painful spending cuts and tax increases to get budget deficits under control. Another argument against carbon taxes is that influential industries will seek exemptions or compensation for the burden of the tax, while low-income households may be unduly burdened from higher energy prices. However, there are some promising ways to deal with these types of challenges, from scaling back pre-existing (redundant) taxes in the energy and transportation system, to reductions in the broader tax system targeted at poor households to production subsidies (and possibly border adjustments) to compensate vulnerable firms. Yet another objection is that governments forgo direct control over their country's emissions, though even this concern may be partly addressed through complementing the policy maximum allowable carbon budgets over a period of years.

Suggested Readings

For a general discussion of pricing policies to address global climate change see

J.E. Aldy, A.J. Krupnick, R.G. Newell, I.W.H. Parry and W.A. Pizer, 2010. "Designing Climate Mitigation Policy." *Journal of Economic Literature* 48: 903-934.

For details on existing emissions pricing programs see

Sumner, Jenny, Lori Bird, and Hilary Dobos, 2010. "Carbon Taxes: a Review of Experience and Policy Design Considerations." *Climate Policy* 11: 922–943.

Heine, Dirk, John Norregaard, and Ian W.H. Parry, 2011. "Environmental Tax Reform: Principles from Theory and Practice to Date." *Annual Review of Resource Economics*, forthcoming.

For a good discussion of administrative issues for carbon taxes see

Metcalf, Gilbert E. and David Weisbach, 2009. "The Design of a Carbon Tax." Harvard Environmental Law Review 33: 499-556.

Linkages between carbon taxes and the broader fiscal system are discussed in

Goulder, Lawrence H., (ed.) 2002. *Environmental Policymaking in Economies with Prior Tax Distortions*. Edward Elgar, Northampton, MA.

The burden of carbon taxes on different household income groups is discussed in

K.A. Hassett, A. Mathur and G. Metcalf, The Incidence of a U.S. Carbon Tax: A Lifetime and Regional Analysis, Energy Journal, 2009, 30:2, 155-175.

On the possible use of stiff carbon taxes to kick start green technological innovation see

P. Aghion , R. Veugelers and C. Serre, Cold Start for the Green Innovation Machine, Bruegel Policy Contribution 2009/12, Brussels.

F. van der Ploeg and C. Withagen, 2012. "Is there really a Green Paradox?" *Journal of Environmental Economics and Management*, forthcoming.

For developing countries, the potential value of funding public spending (with carbon tax revenue) is discussed in

P. Collier, R. van der Ploeg, M. Spence and A.J. Venables, Managing Resource Revenues in Developing Economies, IMF Staff Papers, 2009, 57:1, 84-118.

For some discussion of appropriate policies for addressing CO_2 and other adverse side effects of vehicles see

Parry, Ian W.H., Margaret Walls, and Winston Harrington, 2007. "Automobile Externalities and Policies." *Journal of Economic Literature* XLV: 374-400.

Table 1. Percent Increase in Energy Prices from $22 per ton Carbon, Selected Countries
(for year 2009)

Fuel	Steam coal	Diesel		Electricity		Light Fuel Oil	Natural Gas			Gasoline (regular unleaded)
End user	Generators	Industry	Households	Industry	Households	Households	Generators	Industry	Households	Households
Canada	200.0	7.6	na	8.3	5.8	8.7	na	27.1	11.8	6.2
Taiwan	57.7	8.2	8.2	18.6	15.8	na	10.0	8.9	9.2	6.5
France	44.7	5.1	4.2	1.7	1.1	7.4	na	10.7	5.5	na
Germany	46.2	4.6	3.9	8.5	3.7	8.1	na	8.4	4.1	2.9
Indonesia	72.2	9.3	12.8	25.6	28.0	24.5	35.3	na	na	na
Italy	49.4	4.7	3.9	4.2	4.1	4.1	na	8.4	4.4	na
Japan	na	6.8	5.3	5.8	4.0	8.3	na	8.3	3.0	4.0
Mexico	99.5	11.8	10.3	15.2	16.4	na	23.6	na	11.1	9.2
Netherlands	na	5.1	4.3	7.5	4.1	6.4	na	9.3	4.0	na
Poland	63.3	6.2	5.1	13.4	9.6	7.4	16.7	10.8	5.8	na
Republic of Korea	61.6	na	5.4	16.7	12.6	7.8	10.3	9.8	8.1	4.2
Spain	na	5.4	4.7	9.4	4.6	7.7	na	10.8	5.1	na
Thailand	na	8.2	na	16.8	13.0	5.4	na	16.3	na	5.7
Turkey	158.4	3.5	3.5	9.3	7.8	4.0	10.0	10.0	8.2	na
UK	60.0	4.2	3.6	7.8	5.1	8.6	18.4	14.5	5.8	na
USA	100.8	9.1	9.1	21.8	12.9	8.4	24.9	22.9	10.0	8.4

Sources.
Carbon coefficients for fossil fuels are from www.eia.gov/oiaf/1605/coefficients.html, energy prices are from Energy Prices and Taxes Statistics accessed through OECD ILibrary, and CO_2 per kWh (averaged from 1992-2002) is from http://205.254.135.7/oiaf/1605/pdf/Appendix%20F_r071023.pdf.

Notes.
The absolute price increase for each fossil fuel is given by its CO_2 coefficient per unit (obtained from US data) times $25 per ton. The absolute increase in electricity prices is calculated by the average CO_2 per kWh for generation in a country, times the CO_2 tax. These absolute price increases are compared with prevailing prices in 2009 across different countries to obtain the percent price increase. It is assumed that the tax is fully passed forward—in reality, some of the tax may be passed backwards in the form of lower prices received by fuel suppliers.