PART IV

Policy Options

17 The regulatory approach in US climate mitigation policy

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Climate policy in the United States stalled with the failure to pass comprehensive economy-wide cap and trade in 2010. Despite this setback, policy has continued to form, developing along a separate regulatory track that is on course to allow the US to achieve emissions reductions by 2020 approaching its pledge in Copenhagen. The current regulatory approach to climate policy is directed by the Environmental Protection Agency, which has the authority to regulate greenhouse gases at the national level under the Clean Air Act. This regulatory approach has so far separately targeted the transportation and power sectors, and additional regulations in other sectors are expected. The approach has technical foundations in policies previously implemented by state governments, which it extends through the introduction of national goals. The organic development of policy in the US has an apparent analogue in the international setting as sovereign nations independently prepare pledges and other activities in support of global climate outcomes. The cost of a regulatory approach is likely to be greater than a coordinated effort built on carbon pricing; however, the policy durability of regulation may be as great or greater. Perhaps more importantly, the regulatory approach has initiated a planning process in state capitals that may build a more robust foundation for future policy goals.

In 2009, with the support of a new president, the US House of Representatives passed comprehensive climate legislation including economy-wide cap and trade. Then, the winds of change shifted and the measure, which was never taken up in the US Senate, was left to expire. Cap and trade was declared politically dead. For over two years the president did not utter a word about the changing climate. Many observers thought that

President Obama's pledge in Copenhagen in 2009 to reduce US emissions by 17% from 2005 levels by 2020 was a forgotten promise.

However, out of view of the international community and most political observers, the Obama administration was pursuing a parallel strategy to address climate change through exercising the regulatory authority of the Environmental Protection Agency (EPA) under the Clean Air Act. This chapter summarises the key aspects of this regulatory approach and its expected accomplishments, and discusses its implications for economic efficiency and the prospects for enduring into the future.

1 Increasing the regulatory authority of the EPA

The EPA's authority to regulate greenhouse gases (GHGs) was established under the Clean Air Act and affirmed in a 2007 Supreme Court decision. The court's decision was precipitated by actions already taken by the states that were developing climate policies. The court decision triggered an agency investigation and formal finding of harm from GHG emissions in 2009. Under threat of private lawsuits (a special and unusual provision of the Clean Air Act), the EPA was obliged to move to mitigate that harm. The agency's first actions were finalised in January 2011 with new emissions standards for light duty vehicles and the inclusion of GHGs in the required emissions permitting for new construction of stationary sources. The vehicle standard initiated a 5% annual improvement in the miles per gallon measure of efficiency for new cars that has been extended through the middle of the next decade. The new mobile source standards are expected to contribute to a reduction in carbon dioxide (CO_2) emissions of about 4 percentage points toward the goal of a 17 percentage point reduction by 2020.[1] The preconstruction permitting requirement, which locked in the consideration of GHGs along with other air pollutants in air permitting, will not have much effect in

1 This estimate is based on the US Environmental Protection Agency estimates of turnover in the vehicle fleet. Other estimates in this paragraph and those describing the impact of the Clean Power Plan are based on the author's published research using a detailed simulation model of the power sector and a reduced form representation of the rest of the economy. As described in the chapter by Aldy and Pizer in this book, the comparison of mitigation efforts across nations raises many challenging issues including the validity of models used for that exercise.

the next decade because new construction occurs over a long time frame. The important effect of the permitting requirement will be felt in the long run.

In August 2015, as the centrepiece of this regulatory effort, the president finalised the Clean Power Plan, which aims to reduce emissions from existing power plants that are responsible for about 40% of the nation's CO_2 emissions and about one-third of total GHGs. The Clean Power Plan constitutes the biggest contribution to US emissions reduction efforts to date.

Together with recent changes in US fuel markets, these regulatory initiatives place the US on course to achieve or nearly achieve its Copenhagen pledge, at least with respect to emissions of CO_2. The expanded supply of natural gas and its substitution for coal in electricity generation already accounts for about 3-4 percentage points of the 17% pledge. This contribution might be interpreted as 'business as usual' and not credited to climate policy, but to some extent it results from other strengthened regulatory measures aimed at sulphur dioxide and nitrogen oxide emissions and new regulation of mercury and air toxics from coal power plants. Changes in the electricity sector also reflect extensive federal investments in energy efficiency programmes. Measures taken by state and local governments, including promotion of renewable and energy efficiency technologies, add 2-3 percentage points more. The 17% reduction in emissions that the US hopes to achieve would occur against a backdrop of nearly 30% growth in real terms between 2005 and 2020 in the US economy (CBO 2014).

2 The Clean Power Plan

Before consideration of the Clean Power Plan, measures put in place at all levels of government would achieve roughly 10 percentage points of reduction in emissions compared to 2005 levels. The Clean Power Plan as initially proposed in 2014 intended to add another 6 percentage points or more, placing the US very close to attaining the Copenhagen goal. The final version of the plan delayed full compliance from 2020 to 2022. It retains incentives for investments in renewable energy and energy efficiency beginning in 2020, but the new date will delay the incentive to shift generation from coal to natural gas that is also expected to contribute importantly to emission reduction. The net effect may be a set back with respect to the 2020 goals of the Copenhagen pledge. However, the final plan boosts the stringency of emissions reduction goals over the rest of that decade, compared to the proposed plan.

Burtraw and Woerman (2013) estimate that altogether the regulatory measures taken under the authority of the Clean Air Act, if fully implemented, will result in domestic emissions reductions that are greater than would have been achieved under the comprehensive cap-and-trade proposal that failed to pass Congress. The cap-and-trade proposal embodied an emissions reduction target equal to the Copenhagen pledge, but it allowed for international offsets as a means to meet the target, which would have substituted for domestic emissions reductions. The regulatory measures taken under the authority of the Clean Air Act do not provide a role for international offsets, so emissions reductions are achieved all within the US economy.

To an international audience of policymakers and economists, the structure of the Clean Power Plan is noteworthy because the process it inaugurates mirrors one that is taking shape in international negotiations. As in the US, the international dialogue has moved from the design of a coordinated system to the evolution of an organic one that builds on measures that are taken by sovereign jurisdictions. Individual nations will declare independent nationally determined contributions to mitigating emissions. By analogy, under the Clean Power Plan the US states have responsibility for planning, implementing and enforcing strategies to reduce emissions. The Plan prescribes state-specific emissions rate goals and alternative mass-based equivalents (emissions caps), and states may decide which approach to take. While the state-level goals are federally determined, which solves one aspect of the coordination problem, the policy options available to the states are unconstrained. Each state must choose whether to comply with an emissions rate or emissions cap goal, and submit a plan that demonstrates policies that will achieve the EPA's goal for that state. This presents a substantial coordination challenge, especially among states that operate in the same power market. While this coordination challenge will surely exist within the development of international climate policy, leakage of electricity generation and investment under the Clean Power Plan is potentially much more immediate and sizable than what might be observed internationally in the movement of industrial production (Bushnell et al. 2014, Burtraw et al. 2015).

Also the goals among the states are differentiated, as occurs internationally among nations. The goals are based on a national emissions rate target for coal-fired units and another for natural gas combined cycle units, and are calculated on the basis of the resource mix in a given state, including the opportunity to substitute away from fossil fuels to nonemitting generation. Energy efficiency is given credit under a rate-based approach and contributes directly to compliance under an emissions cap. The technical opportunities vary according to the fuel mix, generation fleet, and resource availability among states, just as technical opportunities vary among nations.

3 The triumph of law and engineering: Assimilating a key economic idea

What is missing in the Clean Power Plan compared to the approach that would be taken by most economists in designing a climate policy is cost-effectiveness – that is, explicit attention to equating the marginal costs of emissions reductions measures throughout the sector and the entire economy. In this sense, the Clean Power Plan is a triumph of law and engineering over economics – law because it is implemented subject to the requirements and constraints of the Clean Air Act, and engineering because the relevant portion of the Act is based on a demonstration of technical opportunity. Because the demonstrated options take into account regional variation, there is some rough alignment of marginal cost, but the Plan does not make cost effectiveness a centrepiece.

However, the EPA has preserved perhaps an even higher order principle from environmental economics — the opportunity for flexible compliance. States can choose to use a tradable emissions rate approach (emissions rate averaging) to achieve compliance, or they can adopt a mass-based equivalent. States can choose from a complete menu of policy approaches to achieve these goals, including cap and trade or emissions taxes, or they can convene a resource planning exercise that is familiar in many states where electricity generation is still regulated.

The flexibility under the Clean Power Plan is of central importance because it gives the regulated entities the tools to negotiate to a cost-effective outcome. Such an outcome is not built in, but it is available and it is likely to be pursued within and among many groups of states. In this sense, the Clean Power Plan differs from traditional prescriptive approaches to regulation and it embodies an important lesson from several decades of economic thinking.

It is also noteworthy that the Clean Power Plan empowers and reinforces the actions of first movers in climate policy among states and local governments. Often these first movers have taken actions that demonstrate the technical opportunities that are the basis for the regional goals. Ten US states have existing cap-and-trade programmes. Twenty-nine states have renewable technology support policies and about 25 have funded energy efficiency policies.[2] This bottom-up leadership has been central to the development of national policy because the accomplishments at the state level are encapsulated in the EPA's findings of technical possibility that underpin the regulation. Paradoxically, comprehensive policies may eliminate the incentive for bottom-up leadership. For example, because cap-and-trade programmes establish a specific tradable quantity of emissions, they have the unanticipated characteristic of imposing not only an emissions ceiling but also an emissions floor (Burtraw and Shobe 2009). With the quantity of emissions established at the national level, measures taken by subnational governments such as energy efficiency measures that overlap an emissions trading program result in 100% leakage (Goulder and Stavins 2011). This characteristic undermines initiatives that might be taken by regulatory agencies, subnational governments or individuals – the type of decentralised initiatives that form the technical foundation for the current regulation.[3]

4 Process and public participation

In contrast to a comprehensive policy that might undermine the contribution of subnational and individual efforts, the Clean Power Plan has launched a substantial process of public participation through planning activities in every state capital that must

2 www.dsireusa.org (accessed August 14, 2015).

3 This is not the necessary outcome when governments introduce a price on carbon and simultaneously promote complementary policies to direct technological development. For example, a tax on carbon will maintain its signal for innovation even as other measures promote directed incentives for technological development. The same outcome is achieved in a cap-and-trade programe if there is a price floor in place. All three North American cap-and-trade programmes (California, Quebec and RGGI) have a price floor.

include interactions with the public. This emphasis on process is a strategy borrowed from the states, and appears to mirror international developments. Keohane and Victor (2013) suggest that for a global climate policy regime to succeed, it is likely to require the learning and coalition-building that is achieved through an incremental process. The public engagement through the Clean Power Plan is unprecedented and deliberate. The outcome of such a process is certainly not guaranteed to be efficient. Conceivably, though, it may help build a decentralised public consensus for action on climate that would not be inherent in national-level comprehensive legislation, and certainly was not part of the debate around cap and trade in the US six years ago.

If fully implemented, the Clean Power Plan will position the US to achieve its Copenhagen pledge with respect to CO_2 emissions. After 2020 it will also yield additional emissions reductions that will contribute to the nation's pledge going into the Paris negotiations for reductions of 26-28% by 2025. But achieving comparable reductions in all greenhouse gases or fully realising the 2025 target will require additional regulations (Hausker et al. 2015). The next ones are expected to be regulation of emissions from heavy-duty trucks, regulation of methane emissions associated with the natural gas industry (including gas extraction and transportation), and regulation of emissions from aircrafts. Others will include regulation of industrial gases. These measures could achieve the Copenhagen pledge and go beyond it. It is not yet clear that policy options using existing regulatory authorities have been identified that will achieve the 2025 target. However, the US is much closer to these targets than many thought possible just a couple of years ago.

5 Efficiency and durability of the regulatory approach

The efficiency of the regulatory approach is difficult to gauge. The cost of vehicle standards depends on the value of fuel savings, which varies directly with the price of gasoline. In the electricity sector, the cost of the Clean Power Plan depends on the ability of states to plan or negotiate to a cost-effective outcome. If they do so, modelling indicates the marginal cost of emissions reductions would be around $20 per tonne of CO_2 reduced (in 2010 US dollars) (Burtraw et al. 2014). If they fail, the marginal costs will vary by a great deal around the country. In the future, the Clean Air Act will require the propagation of new regulations across additional sectors. The marginal abatement costs introduced in other sectors might be calibrated with those introduced under the Clean Power Plan and with the government's estimate of the social cost of carbon (Interagency Working Group 2015). This would give cost effectiveness a prominent if not central role in policy design, thereby achieving most of the efficiency that would be associated with a comprehensive carbon price.

How durable will the regulatory approach be? The US Clean Air Act is a venerable institution that is credited with significant improvements in the nation's air quality, and there is a legal requirement that it address climate change in the future. Hence, the Clean Power Plan is unlikely to be politically overturned even if there were a sweeping shift in election outcomes. More likely, a new administration that opposed the Plan would slow the development of new regulations and starve the budget of the regulatory agency, which could erode the short-run effectiveness of US climate policy significantly. The regulatory effort is already facing legal challenges aplenty, potentially affecting its reach in the power sector, but not stopping it.

Importantly, the requirements of the Clean Air Act to regulate and the specific proposal of the Clean Power Plan have unalterably changed the investment climate in the US electricity sector, whatever the status of the Plan may be going forward. A seemingly irreversible major outcome is the lack of new investment in coal generation capacity and the declining role for coal. Generation from existing coal nonetheless remains significant and it is the major focus of the Clean Power Plan. The authority of the Clean Power Plan to regulate these emissions sources is likely to survive.

Whether a legislated carbon price would accelerate or slow the decarbonisation of the US economy compared to the regulatory approach depends primarily on its price level, although another consideration is the salience of the policy for decision makers. A legislative mandate aimed directly at climate-related goals could be more forceful and comprehensive than the regulatory authority implied by the Clean Air Act. A legislative approach would be entirely politically determined, and only indirectly influenced by technical and economic feasibility. Through legislation, the Congress has unconstrained latitude to implement a direct emissions cap or carbon fee. In contrast, the design and stringency of regulation is indirectly influenced by political considerations, but it is directly based on findings of technical and economic feasibility. If political dynamics are not aligned to promote a robust carbon price, the regulatory process will continue to move forward, at perhaps a slow, but steady pace.

Some observers have offered that comprehensive carbon pricing could be adopted in exchange for removing the potentially inefficient role of current regulation. Congress has the authority to preempt the development of further federal regulations and even some at the state level, which might be possible politically if it were coupled with comprehensive federal policy. Whether this would achieve the most robust carbon policy, the most stringent or the most efficient is uncertain. Innovation must play an important role in addressing climate policy; prices and regulation have different potency in this regard in different sectors and over different time frames.

Whether a regulatory or a legislative approach would be more stringent or enduring is entirely uncertain. Technology-based policies may be less fickle than politically based ones. It is certainly true that a legislative approach could be simpler and more coherent. However, if that approach were coupled with preemption of regulatory authorities it would likely ignite internecine political warfare. An outcome that seems politically achievable and that economists might hope for is the introduction of a comprehensive policy that leaves in place but mostly eclipses the steady but slow-moving regulatory authority that has formed the basis of US emissions reductions to date.

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18 Pricing carbon: The challenges

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In this chapter we provide examples of how carbon taxes can be very efficient in reducing fossil fuel consumption and resulting emissions, focusing on the Swedish experience that shows a significant decoupling of carbon emissions from GDP growth. But only a few countries have seriously implemented carbon taxation. This leads us to discuss political challenges of carbon taxes such as strong lobbying by fossil fuel stakeholders; opposition from the public because of the price impacts of a tax; transparency as to the effects on winners and losers; and the perception that taxes reduce welfare and increase unemployment. The chapter then reviews some of the policy responses to these challenges that share some ambitions and features of carbon taxes but are perhaps easier to implement. These include the removal of fossil fuel subsidies; sectoral carbon taxes such as fuel taxes; cap and trade, exemplified by the EU Emissions Trading System, and regulation; and, finally, the promotion of renewable energy sources exemplified by the German Energiewende. The chapter is concluded with a discussion on lessons learnt and some implications for the international negotiations and the COP in Paris.

1 Introduction

The climate problem can seem, paradoxically, quite simple. There are a series of activities that generate externalities and these should be priced according to the polluter-pays-principle. This could be done through taxes or cap and trade (CAT). There are confounding and complicating aspects such as non-carbon gases and emissions from land use and forestry, but at its core, the problem is simple. Yet there has been

1 Thanks to Amie Svärd and Susanna Olai for excellent research assistance and to the editors and reviewers for insightful comments.

little progress to date in halting the carbon emission rate. Part of the reason is due to politics – some policies are unpopular and therefore policymakers might prefer to deny the underlying problem or procrastinate. There are also powerful fossil fuel lobbies in many countries that influence politics in a very direct way. At the international level, unilateral action is slow and negotiations have several times come to a standstill when burden-sharing and fairness aspects are discussed. Against this background it is instructive to review the experiences hitherto. In this chapter we will briefly review the experiences of carbon taxation at the sectoral and national level, cap and trade in the European Union, and the *Energiewende* in Germany.

2 Carbon tax

A tax on carbon is the most cost-efficient policy in order to reduce carbon emissions according to economists. It is generally more efficient than direct regulation of technology, products, and behaviour, as it affects consumption and production levels as well as technologies, it covers all industries and production and provides dynamic incentives for innovation and further emissions reductions. In addition, the tax revenue can be used to facilitate the transition toward renewable energy, cover administrative and implementation costs, or lower taxes on labour. A tax also continuously encourages industry to reduce emissions in comparison with CAT that only incentivise industry to reduce their emissions to the point of the cap. Furthermore, a tax is easy to incorporate in the existing administration, unlike a cap and trade programme that requires new administrative machinery.

Carbon taxes have existed internationally for 25 years. Finland was the first country to implement a carbon tax in 1990 and the rest of the Nordic countries followed in the early 1990s. Despite the positive aspects of carbon taxes, only a handful of countries beside the Nordic countries have implemented a general tax on carbon of at least US$10/$tCO_2$ to date: the UK, Ireland, Switzerland, and the province of British Columbia in Canada (World Bank 2014). In Sweden, the carbon tax is roughly US$130/$tCO_2$ as of April 2015. The tax is significantly higher than any other carbon tax or CAT permit price across the globe, and it appears to have been very effective in the sectors where it applies. It applies in particular to transport, where gasoline and diesel are taxed strictly in proportion to carbon emissions, but also to commercial use and residential heating as well as partially to industry.[2]

In Sweden and the rest of EU28, buildings contribute to a large part of carbon emissions since almost 40% of final energy consumption comes from buildings (28% residential buildings and 12% non-residential buildings) (European Commission 2014). More than half of all buildings in Sweden are heated by district heating, which in itself is very efficient compared to individual heating of each building. In the last few decades the district heating system has been greatly expanded and a good deal of fuel switching has occurred. Fossil fuels have been phased out and today it relies almost solely on waste and renewable energy sources – thanks to the carbon tax implemented in 1991. The share of oil used for heating decreased in the 1980s to reduce exposure to oil price shocks, but at that time oil was mainly replaced by coal and natural gas. It was not until the carbon tax was introduced that biofuels became the main source of energy for district heating and emissions dropped. Since 1980, output has almost doubled in the district heating sector while carbon emissions have decreased by 75% (Svensk Fjärrvärme 2015). The latest decrease in emissions came in 2003 after the implementation of the Tradable Renewable Electricity Certificates scheme.[3] Together with the carbon tax and building regulations, this scheme has reduced average energy usage in buildings in Sweden significantly.

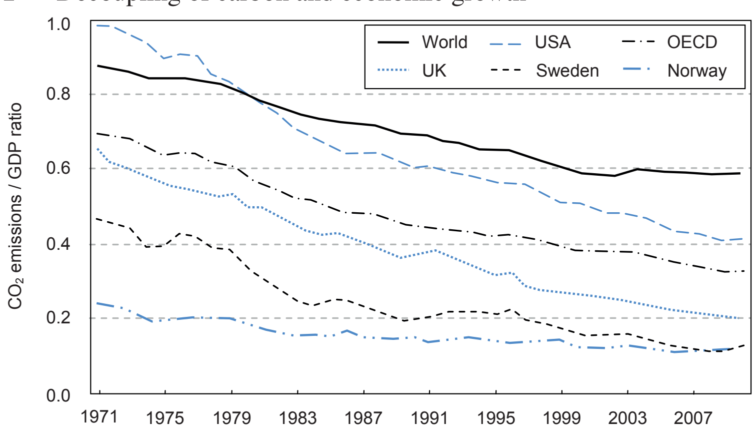
The likelihood that a carbon tax will be the only instrument in place on a global scale looks minuscule. As discussed in Chapter 15 of the latest (fifth) IPCC Assessment

2 Industry pays reduced (but still high by international standards) carbon tax rates but also has exemptions and major industries participate in the EU ETS instead of paying taxes in order to avoid double taxation.

3 The Tradable Renewable Electricity Certificate scheme was introduced in Sweden in 2003. For every MWh of renewable electricity generated, producers obtain a certificate from the state. These are then sold in an open market, where the market determines the price. Certificates therefore represent extra revenue for renewable energy producers. Buyers, mainly electricity suppliers, have quota obligations to purchase certificates. Renewable energy that qualifies under the scheme includes wind power, certain hydropower, certain biofuels, solar energy, geothermal energy, wave energy and peat in CHP plants. New generation plants qualify for 15 years, and quota levels are defined until 2035. In 2012, Sweden and Norway created a joint electricity certificate market with a common target of increasing renewable electricity production by 26.4 TWh between 2012 and 2020. The two countries contribute with 50% of financing each, however the market will decide where and when new production will occur. Since its inception, the Swedish-Norwegian certificate system has already contributed with 10.3 TWh of new renewable production capacity (Swedish Energy Agency 2015).

Report, countries normally rely on a combination of several instruments with different targets simultaneously, as exemplified by the experience of the Swedish building sector, described above. Therefore, it is difficult to assess the efficiency and environmental impact of carbon taxes. In Sweden, between 1990 and 2007, there was a decline in CO_2 emissions by 9% while the country's economy experienced a growth of 51%. There was a strong decoupling of CO_2 emissions and economic growth and the carbon intensity of GDP was reduced by 40% (Johansson 2000, Hammar et al. 2013). However, it is important to note that these figures reflect only emissions from production within countries. Products manufactured abroad and consumed in Sweden are not taken into account. Looking at emissions domestically, the Swedish carbon tax has so far proven to be both cost effective and efficient in achieving the commitment in the Kyoto Protocol. Greenhouse gas emissions have decreased by 22% since 1990, and the next domestic goal is to decrease emissions by 40% from 1990 to 2020 (Naturvårdsverket 2015). As Figure 1 shows, there is a clear trend over the last 40 years of decreasing CO_2 emissions per unit of GDP. Sweden's emissions per unit of GDP are about one-third of the world average.

Figure 1 Decoupling of carbon and economic growth



Source: IEA (2012).

3 Political challenges with carbon tax

In the 1990s, the EU tried to implement a tax but failed for several reasons. Ministers of finance are notoriously unwilling to compromise on taxes and give up their prerogative on tax issues to supra-national authorities. Taxes are viewed as a national concern and central for domestic economic policy. Another reason was the reluctance of letting the EU decide on yet another area of policy, moving the decision-making power from the national to the European level. But let us not forget that, in the 1990s, climate change was not the burning issue it is today, which made it hard to implement effective policy that would substantially reduce carbon emissions. This has led many to the unsubstantiated conclusion that carbon taxes do not work and are impossible to implement.

Globally there are even more reasons why countries have failed to implement carbon taxes: (i) strong lobbying by fossil fuel stakeholders; (ii) opposition from the public because a tax will raise prices; (iii) transparency as to the effects on winners and losers compared to the much less visible cost of regulations (Brännlund and Persson 2010); (iv) a perception that taxes reduce welfare and increase unemployment due to lower levels of consumption and production (Decker and Wohar 2007); and (v) possible institutional path dependencies that led to favouring cap and trade (Paterson 2012). In the absence of direct carbon pricing, countries have tried a number of other responses outlined below.

3.1 Response 1: Removal of fossil subsidies

Closely linked to taxes, but at the other end of the green fiscal reform scale, is the major issue of removing energy subsidies. Not only do energy subsidies damage the environment in various ways, they also discourage investment in renewable energy and energy efficiency, and impose a large fiscal burden (Coady et al. 2015). Subsidies need to be financed and this usually happens by increasing public debt or taxes on labour or goods. Subsidies also crowd out essential public spending on, for example, health and education. Some view energy subsidies as a way of providing support for low-income households, but subsidies are a highly inefficient way to support disadvantaged groups since the rich capture most of the benefits (Sterner 2011). Of course, there are political challenges in compensating the losers of a subsidy removal reform, but that discussion is beyond the scope of this chapter. Either way the current low oil prices provide a unique opportunity to shed such subsidies (Fay et al. 2015).

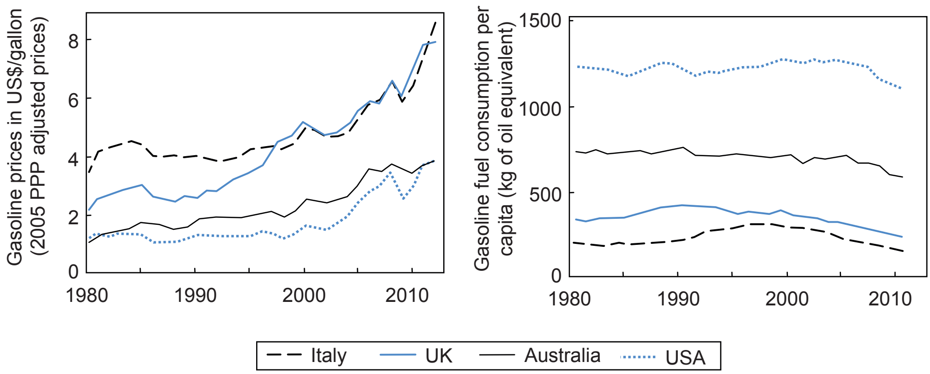
3.2 Response 2: Fuel taxation

Instead of a carbon tax, a closely related policy instrument that also has a major impact on carbon emissions is excise taxes on goods that have a high fossil carbon content. The prime example is a fossil fuel tax. A fuel tax is essentially a tax on carbon in the transport sector – a tax that is sometimes easier to implement than a carbon tax. As a result, there are more taxes on fuel than carbon around the world and, consequently, more studies and evidence of the performance of fuel taxes. Studies conclude that fuel has low price elasticity in the short run of somewhere between -0.1 and -0.25. This means that if the price of fuel increases by 1%, consumption would decrease by between 0.1% and 0.25% during the first year of implementation. This low effect is probably due to slow-moving structures such as habits, infrastructure, or technology. However, in the long run, surveys have shown the price elasticity of fuel to be about -0.7 on average (Graham and Glaister 2002, Goodwin et al. 2004).

In Europe and Japan, fuel taxes have reduced CO_2 emissions by more than 50%. According to various studies, fuel taxation is the policy that most likely has had the greatest impact on global carbon emissions (Sterner 2007). Fuel taxes not only impact total consumption by changing individual behaviour (e.g. driving fewer miles), they also create incentives for companies to invent fuel saving technology and greener cars. In Figure 2 we see how fuel prices affect demand in two high fuel-price countries (Italy and the UK) and two low fuel-price countries (the US and Australia). The two extremes are Italy and the US, with Italy having a fuel price three times that of the US. The US, on the other hand has a per capita consumption more than four times that of Italy.[4]

4 Per capita consumption is of course not *only* affected by prices, but prices *are* important (Sterner 2011).

Figure 2 Gasoline prices and gasoline fuel consumption per capita in four countries



A commonly used argument against fuel taxes is that they are regressive, that those who are poor pay a larger share of their disposable income on fuel and taxes. Sterner (2011) has empirically shown that this is not generally the case – in many developing and low-income countries, fuel taxes are *progressive* and a valuable source of revenue for the state. The progressivity depends on location, the design of the policy, and the type of fuels covered. In Europe, the distributional effects are basically neutral while studies in the US do actually display some regressivity (Metcalf 1999, Hassett et al. 2009). However, if the US government would take action and recycle the revenue from fuel taxation back to consumers, fuel taxation could be made progressive (West and Williams 2012, Sterner and Morris 2013).

3.3 Response 3: Cap and trade, and regulation.

In contrast to a tax, cap and trade (CAT) regulates the quantities of emissions, not the price – an advantage for a regulator who really wants to be assured of a given decline in emissions. The idea is that permits to emit CO_2 are created and allocated to industries, giving them the right to emit CO_2. They need a permit for every ton of CO_2 they emit. If they reduce their emissions they can sell their excess permits, while they would have to buy permits if their emissions are above the quantity of permits they own. Permits in a CAT programme are allocated either by auction, free allocation, or a mix of both approaches. With an auction, the government raises revenue just as with a tax, while there is clearly no revenue raised with free allocation. In the latter case the decision-maker must however decide on a mechanism for the free allocation. One of these is benchmarking that is roughly in proportion to output, and another is grandfathering based on historical emission levels. Each comes with some advantages and disadvantages.

The EU Emissions Trading Scheme (ETS) is the world's largest carbon CAT programme, covering roughly 45% of the EU's total GHG emissions (European Commission 2013). Estimates of the emission reductions achieved by the first (2005-2007) and second (2008-2012) phases of the programme, calculated relative to forecasts of emissions, have in general been modest (Ellerman et al. 2010, Anderson and Di Maria 2010, Georgiev 2011). In a recent paper, Bel and Joseph (2015) conclude that the main driver of decreasing emissions was the Global Crisis in 2008/2009 rather than the EU ETS. The effectiveness of the EU ETS is often considered to be compromised due to a lenient allocation of permits in the first two phases. It seems to have been politically difficult to put in place a tight cap on the programme. However, in its third phase the cap will be reduced by 1.74% annually. Hence we know that emissions will fall relative to historical levels. Currently, permit prices are still low – though those who defend CAT say that this is due largely to ancillary policies and external conditions.

Unfortunately, carbon CAT programmes have not been the success story many had hoped for. The caps have been set too high, and as a consequence the prices of permits have been too low to achieve sufficient reductions. One reason for this is heavy lobbying from the industry. Industry has also lobbied for grandfathering (IPCC 2014). Burtraw and Palmer (2008) calculate that if as little as 6% of the pollution permits in electricity generation are grandfathered and the rest are sold by auction, industry profits would be maintained. Allocating more than about 10% for free leads to windfall profits. CAT has been found to be regressive to a certain degree, but, at least in richer countries, poor people generally have their cost offset by social welfare programmes (Blonz et al. 2012).

Politicians are worried that a tight cap will hurt their industries. If they were to agree to a tight cap and the economy would boom, the big concern is that this would lead to rocket-high prices of permits. Such concerns lead to over-allocation because companies and politicians want to avoid very high prices. Many politicians do not trust CAT to work or they are concerned about agreeing on a cap that is too tight. Instead (or in addition), they implement other types of regulation such as renewable energy certificates to complement the policy and this in turn contributes to the low permit prices. Hence, unlike carbon taxes that can be complemented with other policies, CAT schemes cannot easily be complemented in this way.

In the US, attempts to introduce CAT have succeeded in some states, notably California, but at the federal level they have so far failed. The US is currently turning instead to fairly large-scale implementation of simple regulation in various areas related to climate change emissions.

An interesting and important question is how different national instruments such as cap and trade or carbon taxes will operate within international agreements. Up till today, most negotiations have focused on quantitative allocations or undertakings by different countries. This might be realised through a linking, for instance, of cap and trade schemes. The issues involved are however far from straightforward. It is difficult to link schemes without a full agreement on future targets (which is the most contentious part of the international negotiations).[5] There are therefore alternative suggestions about structuring international negotiations around agreed minimum prices (Nordhaus 2015, Weitzman 2014).

3.4 Response 4: Promoting renewable energy

Progress on effective policy instruments and on international treaties is thus in general poor. Both taxes and CAT are strongly resisted. Becoming carbon neutral is not only about reducing our carbon emissions. It is also (and perhaps more importantly) about creating new energy infrastructure made up of renewables such as solar, wind, and hydro.[6] Up till today, renewables have needed government support to be a viable option for households and industry, but the price gap between fossil and renewable energy is

5 See Green et al. (2014) or Stavins (2015) for different views of the pros and cons of linking CATs across jurisdictions.

6 See the chapter by Toman in this book for a more elaborate review of approaches to increase the use of renewables.

decreasing very quickly.[7] We believe this is a vital issue to discuss in combination with taxes because of the dynamic effect of relative prices between renewable energy and fossil fuels. When renewable energy becomes cheaper than fossil fuels the market takes over the transition. Since the price gap is now small, this can be induced by carbon taxes or subsidies on renewables – or a combination of both.

The political power in subsidising renewable energy in order to close the gap between fossils and renewables has been well demonstrated by Germany. For at least 15 years,[8] Germany has pursued energy transition (*Energiewende*), an initiative to facilitate the transition from nuclear- and coal-powered energy generation to renewable sources within the next four decades. Targets include reducing GHG emissions by 80-95% compared with 1990, increasing energy efficiency to reduce usage by 50%, and increasing the share of renewable sources in energy consumption to 80%. The transition focuses mainly on increasing solar and wind power as these sources are the most cost-efficient renewable technologies to date (Agora Energiwende 2013). Between 2000 and 2014, the share of renewable energy consumption increased from 6% to 27% (BDEW 2014).

So far, even though the use of renewables has increased dramatically, carbon emissions per kWh have not dropped very much. This is because Germany is trying to reduce carbon emissions and phase out nuclear power by 2022 simultaneously (Agora Energiwende 2014). A positive externality from the Energiewende is a lower cost of renewables for the rest of the world through know-how and technological innovation. However, the initial levels of the feed-in tariff implemented in 2000 guaranteed 20 years of fixed and very high prices for solar and wind producers, and people rushed to install solar panels and expand wind farms. This caused the desired expansion in

7 According to Bloomberg New Energy Finance (2014), the average global cost of solar PV electricity has fallen by more than 50% in the past five years, while the cost of wind power has fallen by about 15% in the same time period. The cost of electricity generation from coal and natural gas has not changed significantly during this period. The estimated global cost of electricity generation from wind power is close to that of coal power, while the cost of natural gas generation is still lower than both wind power and coal. The cost of solar PV electricity is currently roughly twice as that of natural gas. However, that will change if the trend of rapidly falling system costs continues. Note that electricity generation costs vary widely locally.

8 The *Erneuerbare-Energien-Gesetz* (Renewable Energy Sources Act or EEG) was adopted in 2000.

supply of electricity, but the subsidy became more expensive as supply increased. The tariffs have been lowered considerably but the cost (shared amongst all households) is still quite substantial. Early investors were able to guarantee a very good return on their investment.

The *Energiewende* technology policies have been very successful in increasing supply and bringing down the price of renewables. This has shifted the balance of power among lobbies, weakening the fossil lobby and strengthening the green lobbies and thereby making other policies such as carbon taxes more likely. There are, however, difficulties when transitioning to renewable energy sources at a national level – solar and wind are intermittent, and energy in general is expensive to store. These are challenges that a renewable energy system has to address and this is going to require considerable modifications of the traditional utility business model, including incentives for storage, transmission, and time-of-day pricing to help steer demand.

4 Lesson learned – now what?

When carbon taxes felt politically out of reach, policymakers decided to opt for cap and trade – to set a quantity of emissions rather than a price. What we have learned, however, is that it is as difficult to negotiate a quantity as it is a price. With a quantity it is more apparent who are the 'winners' and 'losers' in a negotiation. Previous negotiations have come to a standstill because of distribution and fairness aspects. In the global context, large countries such as India will benefit if quantities are allocated on a per capita basis, whereas countries with large historical emissions such as the US will benefit from grandfathering.

To facilitate the negotiation process in Paris, there are, as mentioned above, academics who argue that the focus should shift towards prices rather than quantities. A variety of reasons are mentioned, for instance to make the treaty and its implementation more incentive compatible (Nordhaus 2015) or because it is easier to negotiate just one number rather than a quantity (Weitzman 2014). When discussing quantities, it is not apparent what the related cost would be for industry, while a price is, in this sense, more transparent. It is possible that the future regime and negotiations will include many instruments (possibly for different parts of the climate change complex – different sectors, gases, etc). The aim of the negotiations might include not only quantitative commitments but also a price floor – or possibly a tax per tonne of carbon. Countries will then be free to opt for just the minimum level or – a higher level as in the case of Sweden – to raise the bar and encourage consumers to become energy efficient and industry to invest in research and development of new technology. The price floor would increase the global efficiency of carbon mitigation and reduce the risk of leakage and pollution havens, while at the same time the market would receive a clear signal to invest in renewable energy technology and emission abatement.

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19 Taxing carbon: Current state of play and prospects for future developments

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Pricing carbon is emerging as an essential element for achieving global mitigation targets, providing a necessary signal for investments in low-carbon and resilient growth. Depending on each country's different circumstances and development priorities, various instruments (such as domestic emissions trading schemes or carbon taxes) can be used to price carbon and efficiently and reduce emissions in a cost-effective manner.

In 2015, about 40 national and over 20 sub-national jurisdictions are putting a price on carbon, representing almost a quarter of global GHG emissions, with the value of existing carbon taxes around the world being estimated at US$14 billion. Despite successful experiences and lessons that have been generated over the years of carbon tax implementation, the challenges that countries face when designing and implementing carbon taxes are not to be underestimated.

That said, the progress countries have shown so far is indisputable. With a uniform global carbon price being difficult to envisage in the near future, these on-the-ground efforts to use market forces to curb emissions are critical for any global mitigation efforts, potentially paving the way for the emergence of an international coordination mechanism for carbon pricing.

1 The findings, interpretations and conclusions expressed herein are those of the authors and do not necessarily reflect the view of the World Bank Group, the Partnership for Market Readiness or the governments they represent. The World Bank does not guarantee the accuracy of the data included in this work. The boundaries, colors, denominations, and other information shown on any map in this work do not imply any judgement on the part of The World Bank concerning the legal status of any territory or the endorsement or acceptance of such boundaries.

1 National context: A key driver behind countries' choice of carbon-pricing instruments

1.1 A wide variety of carbon-pricing instruments

Closing the gap between the 2°C target and our current climate trajectory requires a set of pragmatic policy and competitiveness solutions that support national development goals, while lowering carbon emissions. With the 2015 deadline for a global climate deal drawing nearer, policymakers around the world have been increasingly looking at carbon pricing to meet the challenge of achieving global mitigation targets, while providing a necessary signal for investments in low-carbon and resilient growth.

1.2 National political economy matters

Depending on their different circumstances and development priorities, countries opt for various instruments to price carbon efficiently and reduce emissions cost effectively. Considerations behind countries' choices of a carbon-pricing instrument can be of a political, economic, institutional, or social nature, to name a few. In some cases, it is easier to introduce one instrument as opposed to another. Moreover, specific design features can reduce opposition to the instrument of choice without jeopardising environmental effectiveness.

South Africa is a case in point. With a majority of the country's GHG emissions coming from the energy sector and the oligopolistic nature of the energy market which is dominated by a few companies, a carbon tax was an evident choice. Simply put, the lack of energy industry players would likely reduce the efficiency gains that would normally result from an emissions trading scheme (ETS). Moreover, several studies modelling the broad macroeconomic impact of a carbon tax for South Africa have indicated that the tax could be an important instrument for achieving the country's mitigation objectives at a reasonable cost to the economy, especially if coupled with one or more revenue recycling options (World Bank 2015).

China, on the other hand, has opted for a market-based instrument. With the support of the World Bank's Partnership for Market Readiness (PMR), the national government is intensifying its preparation for the design of a national ETS, which is expected to be launched in 2017. The ETS will cover major industry and power sectors, which are the major drivers for GHG emissions. A national ETS is expected to play a critical role in using market means to reduce emissions at scale but in a cost effective way.

1.3 Carbon tax versus ETS: Not so different?

While the choice between an ETS and carbon tax is mainly driven by political economy considerations, the similarities between the two approaches are greater than the differences. Moreover, the design details are more important than the choice of instrument itself. For instance, many emissions trading schemes demonstrate a trend of including 'hybrid' elements, such as price floors or market stability reserves. To this end, the UK's carbon price floor (CPF) is in fact a tax on fossil fuels used to generate electricity. Some tax schemes also include similar 'hybrid' elements, such as carbon offset schemes. South Africa is again a good example of such an approach, currently exploring how offsets could complement its carbon tax and serve as a flexibility mechanism that would enable industry to deliver least-cost mitigation and therefore lower its tax liability. In order to ensure the effective implementation of both a carbon tax and a complementary offset mechanism – and ultimately facilitate transition towards a low-carbon economy – design features need to be well thought through. In the case of South Africa, the carbon offset eligibility criteria include South African-based credits only.

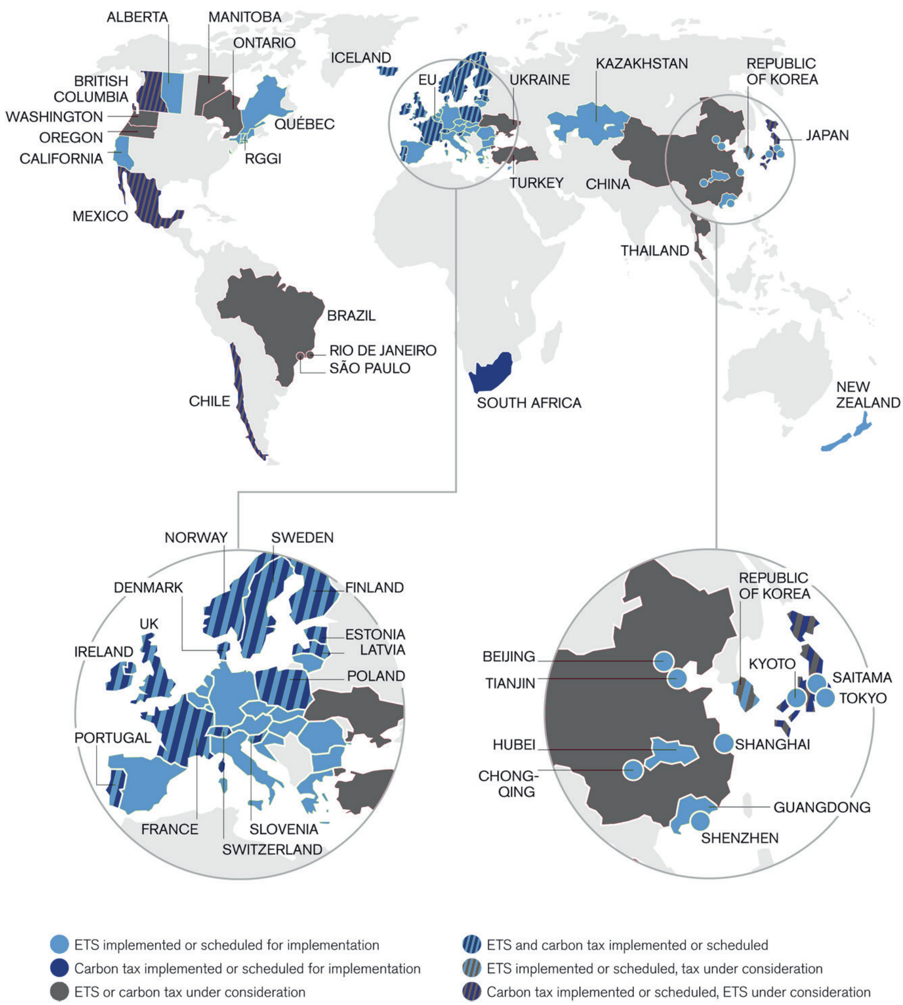
2 Carbon tax around the world: Overview and recent developments

2.1 Carbon tax at a glance

A carbon tax refers to a tax directly linked to the level of CO_2 emissions, often expressed as a value per tonne CO_2 equivalent (per tCO_2e). Carbon taxes provide certainty in regard to the marginal cost faced by emitters per tCO_2e, but do not guarantee a maximum level of emission reductions, unlike an ETS.[2]

2 Based on OECD (2013).

Figure 1 Summary map of existing, emerging, and potential regional, national and subnational carbon pricing



Source: World Bank (2015b).

Carbon taxes can be implemented as 'upstream taxes' (on the carbon content of fuels), 'downstream' taxes (on emitters), or some combination of the two. In all cases, the main policy issues concern determining the tax base, the tax rate, the use of revenues, compensation mechanisms for industries and households, if any, and coordination and interaction with other policies.

2.2 Overview of existing and emerging carbon taxes

Today, about 40 national and over 20 sub-national jurisdictions, representing almost a quarter of global GHG emissions, are putting a price on carbon (see Figure 1 and the Appendix) (World Bank 2015b). These carbon-pricing instruments cover about half of the emissions in these jurisdictions, which translates into approximately 7 GtCO_2e, or about 12% of annual global GHG emissions (World Bank 2015b). The value of global ETSs as of 1 April 2015 is about US$34 billion, while the existing carbon taxes around the world are estimated to be valued at $14 billion (World Bank 2015b).

2.3 Carbon tax experience in developed countries and jurisdictions

Carbon taxes were first adopted in Europe in the early 1990s and were often introduced alongside another carbon-pricing instrument, such as an energy tax (see also the contribution by Sterner and Köhlin to this book). While the experience with direct carbon tax implementation is relatively new, a number of important lessons can be drawn, as illustrated by the examples of Norway, Sweden, and British Columbia.

Norway introduced its carbon tax in 1991, which covers all consumption of mineral oil, gasoline and natural gas. It is, therefore, estimated that approximately 50% of the country's total GHG emissions are covered by the carbon tax. Emissions not covered by the carbon tax are included in Norway's emissions trading scheme (ETS), which was linked to the European ETS in 2008. Depending on the fuel type and usage, the tax rate varies between 25–419 krone/tCO_2 (US$4–69/t$CO_2$) (Kossoy et al 2014).

Sweden introduced its carbon tax in 1991, mainly as part of the energy sector reform. The major sectors included in Sweden's carbon tax system are natural gas, gasoline, coal, light and heavy fuel oil, liquefied petroleum gas (LPG), and home heating oil. While households and services are fully covered by the carbon tax, non-ETS industry and agriculture are partially exempted. Over the years carbon tax exemptions have increased for installations under the EU ETS, as opposed to directly providing exemptions to all GHG emissions covered under the EU ETS. The tax rate is 1,076 krone/tCO2 (US$168/t$CO_2$), as of January 2014 (Kossoy et al 2014).

British Columbia introduced a carbon tax in 2008, applicable to the purchase or use of fuels within the province. The main objective of the tax is to encourage low-carbon development without increasing the overall tax burden. For this reason, British Columbia's carbon tax is revenue neutral, which means that all the funds generated by the tax are returned to the citizens through reductions in other taxes, such as in personal and corporate income tax and tax credits. After seven years of implementation, British Columbia's carbon tax has been generally supported by the public, and has achieved significant environmental impacts without compromising economic development (Kossoy et al 2014). For instance, from 2008 to 2011, British Columbia reduced its GHG emissions per capita from sources subject to the carbon tax by a total of 10%, while the rest of Canada only reduced their emissions from the same source types by 1% over the same period (Elgie and McClay 2013).

2.4 Carbon taxes in emerging economies

Emerging economies are taking action, too. Recent noteworthy developments include passage of carbon tax legislation in Chile in 2014, further refinements to the design of a carbon tax in South Africa, and implementation of a carbon tax in Mexico.

Chile, as part of a major tax reform, is introducing a carbon tax that will regulate CO_2 emissions, as well as local pollutants, produced by fixed sources used for thermal power generation. The carbon tax is expected to enter into force in 2017 and is envisioned to be designed as a tax on emissions from boilers and turbines with a thermal input equal or greater than 50MW (Kossoy et al. 2014). With an additional analysis to examine the impact of proposed carbon tax in the works, initial assessments suggest that approximately 50% of energy in the country will be taxed. While further analytical work is needed, it is clear that carbon tax design and implementation will carry a number of challenges – including technological changes in the energy sector and the implications on international competitiveness, to name a few.

South Africa is working on a carbon tax scheme, which could be launched in 2016 if the Parliament adopts the legislation. The proposed rate is set at RND120 (US$11.20) per tonne of CO_2e, with a yearly increase of 10% until 2019/2020. However, the 'effective' rate is much lower – between US$1 and US$4 due to a relatively high tax threshold and 'exemptions' (World Bank 2015a). The tax is envisioned to be a fuel input tax, based on the carbon content of the fuel used, and will cover all stationary direct GHG emissions from both fuel combustion and non-energy industrial process emissions, amounting to approximately 80% of the total GHG emissions. The carbon tax and accompanying tax incentives, such as an energy-efficiency tax incentive, are expected to provide appropriate price signals to help shift the economy towards a low-carbon and sustainable growth path. A complementary offset scheme is also proposed, though its parameters have yet to be finalised. The offset scheme aims to provide flexibility to taxpayers, leading to a lowering of their tax liability, as well as to incentivise mitigation in sectors not directly covered by the tax (World Bank 2015a).

Mexico's carbon tax on fossil fuel import and sales by manufacturers, producers and importers, which came into effect in 2014, covers approximately 40% of the country's total GHG emissions. Depending on the type of fuel, the tax rate is \$10–50 pesos/tCO_2 (US\$1–4/tCO_2). Mexico's carbon tax is not a tax on the carbon content of fuels, but rather on the additional amount of emissions that would be generated if fossil fuels were used instead of natural gas. Therefore, natural gas is not subject to the carbon tax. The tax also allows for the use of offsets. Companies may choose to comply with their commitments by buying offset credits from domestic Clean Development Mechanism (CDM) projects – equivalent to the market value of the credits at the time of paying the tax – therefore promoting the growth of mitigation projects in Mexico and the creation of a domestic carbon market (World Bank 2015a).

3 Carbon tax design and implementation: Key lessons

3.1 The case for a carbon tax

While a carbon tax (unlike the ETS) does not guarantee the maximum level of emission reductions, this economic instrument can be used to achieve a cost-effective reduction in emissions.

First, since a carbon tax puts a price on each tonne of GHG emitted, it sends a price signal that gradually causes a market response across the entire economy, creating a strong incentive for emitters to shift to less GHG-intensive ways of production and ultimately resulting in reduced emissions.

Second, a carbon tax can also raise substantial amounts of government revenue, which can be recycled towards low-carbon development investments, reductions in other taxes, or funding of other government programmes and policies. Chile is a case in point – its carbon tax is expected to increase revenues for funding the national education reform.

Moreover, carbon taxes can further improve national welfare through various co-benefits, such as improvements in health or a reduction in local pollution.

Last but not least, by reducing GHG emissions that are driving global warming, national carbon taxes also have global benefits.

3.2 Common challenges to carbon tax implementation

Despite these advantages, the many challenges that countries face when designing and implementing a carbon tax are not to be underestimated.

First, it is often argued that carbon taxes tend to have a disproportionate impact on low-income households. In reality, there are different mechanisms and policies that are targeted at protecting low-income individuals and families, and the experience of British Columbia's carbon tax attests to this. Its revenue recycling mechanism, which includes various tax cuts and credits for low-income households to offset their carbon tax liabilities, is a good example how this challenge could be overcome (see also the contribution by Sterner and Köhlin in this book).

Second, many political challenges could arise from issues around carbon leakage, i.e. if the introduction of a carbon tax in one jurisdiction leads to a relocation of economic activity to jurisdictions where carbon taxes are not in place – a matter of concern especially for industrial competitiveness (see the contribution by Fischer in this book.). Despite the importance that these issues have been given in policy debates around the world, a number of approaches can help mitigate the risks of carbon leakage – ranging from measures that are integrated into the design of a carbon tax, such as tax exemptions and credits, to those that exist alongside a carbon tax, such as financial and institutional support for emission reductions investments, energy efficiency improvements, and so on.

Moreover, careful management and coordination of a carbon tax with other existing or planned policies is critical in order to avoid overlapping and uncoordinated efforts. Good practice demonstrates that, when designing a carbon tax, countries typically look across the entire portfolio of policy measures that put a price on carbon and assess their cost-effectiveness, as well as consistency with other climate policies. Engaging in policy-mapping exercises in this regard ensures that new policies align with the existing ones and contribute to countries' overall efforts to achieve medium- and long-term mitigation objectives.

Finally, countries often face significant practical challenges during carbon tax implementation (in particular, 'downstream' taxes) in regard to data on current and projected emissions, technical infrastructure for monitoring reporting and verification (MRV) of emissions (see also the contribution by Weiner to this book) or legal rules and procedures for implementation, to name a few. What is important to stress is that improving carbon-pricing readiness in terms of technical and institutional capacity sets a foundation for the implementation of a forthcoming carbon-pricing instrument. Regardless of whether a country ultimately implements a carbon-pricing instrument, building and improving such readiness is a no-regrets measure, which has cross-cutting benefits that support domestic climate change policies and low emissions development.

4 Looking ahead: Options for global carbon pricing

4.1 Carbon tax: A domestic policy with a global reach

As noted in the case of countries and jurisdictions with long-standing experience of carbon tax implementation, a carbon tax promises a number of national co-benefits – from encouraging low-carbon alternatives and shifts in technology to raising revenues and ultimately leading to a socially efficient outcome. Additional to these benefits, of course, is a contribution to global efforts to curb emissions.

Despite facing many challenges when designing and implementing carbon taxes and other carbon-pricing instruments, the progress that countries have made so far is indisputable. These on-the-ground efforts to use market forces to curb emissions will be critical for any global mitigation efforts.

4.2 Coordinated efforts are key to achieving global mitigation targets

Paris is hardly an end goal, but it is surely an important milestone. For the global climate regime to be successful, the Paris agreement must reinforce our collective ambition and provide a clear pathway to net zero GHG emissions before the end of the century. Equally important for the agreement will be to draw on individual country contributions and include comparable mitigation targets from major economies. Since it is difficult to envisage a globally uniformed carbon price in the near future, an international coordination mechanism may be necessary to enhance a dialogue across different jurisdictions, to promote transparency in the process of price setting, as well to overcome some of the perpetual challenges – such as issues around carbon leakage – that countries face when putting a price on carbon.

That being said, it is encouraging to see that a number of bottom-up initiatives for fostering the international cooperation on carbon pricing have already taken root. For example, the World Bank's Partnership for Market Readiness (PMR),[3] established in 2011, brings together the world's major economies that are pursuing various carbon pricing instruments, including those that are preparing to implement a carbon tax. As an illustration, the PMR supports efforts by Chile and South Africa to design and implement their respective carbon taxes, including looking at the issues around the use of offset mechanisms, exploring interactions between the carbon tax and other existing polices and measures, building technical foundations for the tax implementation, and so on.

Through the PMR platform and other relevant initiatives on the subject matter, policymakers share valuable knowledge on technical and policy challenges faced during

3 PMR Participants are: Brazil, Chile, China, Colombia, Costa Rica, India, Indonesia, Jordan, Mexico, Morocco, Peru, South Africa, Thailand, Turkey, Tunisia, Ukraine, Vietnam, Kazakhstan, Australia, Denmark, the European Commission, Finland, Germany, Japan, the Netherlands, Norway, Spain, Sweden, Switzerland, the UK and the US. For more information about the PMR and its participants, see https://www.thepmr.org

the design and implementation of carbon tax and other carbon-pricing instruments. By facilitating efforts to establish common standards for GHG mitigation and supporting pricing schemes to become more open and transparent, it is not inconceivable that the international coordination mechanism on carbon pricing could emerge from such bottom-up initiatives, ultimately helping us get on a path to zero net emissions before the end of the century.

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Appendix: Overview of carbon taxes around the world

	Country/ jurisdiction	Type	Year adopted	Overview/coverage	Tax rate
1	British Columbia	Sub-national	2008	The carbon tax applies to the purchase or use of fuels within the province. The carbon tax is revenue neutral; all funds generated by the tax are returned to citizens through reductions in other taxes.	CA$30 per tCO_2e (2012)
2	Chile	National	2014	Chile's carbon tax is part of legislation enacted in 2014. The carbon tax is expected to enter into force in 2017 (currently it is being debated in the Senate) and is envisioned to be designed as a tax on emissions from boilers and turbines with a thermal input equal or greater than 50 thermal megawatts (MWt).	US$5 per tCO_2e (2018)
3	Costa Rica	National	1997	In 1997, Costa Rica enacted a tax on carbon pollution, set at 3.5% of the market value of fossil fuels. The revenue generated by the tax goes toward the Payment for Environmental Services (PES) programme, which offers incentives to property owners to practice sustainable development and forest conservation.	3.5% tax on hydrocarbon fossil fuels
4	Denmark	National	1992	The Danish carbon tax covers all consumption of fossil fuels (natural gas, oil, and coal), with partial exemption and refund provisions for sectors covered by the EU ETS, energy-intensive processes, exported goods, fuels in refineries and many transport-related activities. Fuels used for electricity production are also not taxed by the carbon tax, but instead a tax on electricity production applies.	US$31 per tCO_2e (2014)
5	Finland	National	1990	While originally based only on carbon content, Finland's carbon tax was subsequently changed to a combination carbon/energy tax. It initially covered only heat and electricity production but was later expanded to cover transportation and heating fuels.	€35 per tCO_2e (2013)
6	France	National	2014	In December 2013 the French parliament approved a domestic consumption tax on energy products based on the content of CO_2 on fossil fuel consumption not covered by the EU ETS. A carbon tax was introduced from 1 April 2014 on the use of gas, heavy fuel oil, and coal, increasing to €14.5/tCO_2 in 2015 and €22/tCO_2 in 2016. From 2015 onwards the carbon tax will be extended to transport fuels and heating oil.	€7 per tCO_2e (2014)

	Country/ jurisdiction	Type	Year adopted	Overview/coverage	Tax rate
7	Iceland	National	2010	All importers and importers of liquid fossil fuels (gas and diesel oils, petrol, aircraft and jet fuels and fuel oils) are liable for the carbon tax regardless of whether it is for retail or personal use. A carbon tax for liquid fossil fuels is paid to the treasury, with (since 2011) the rates reflecting a carbon price equivalent to 75% of the current price in the EU ETS scheme.	US$10 per tCO_2e (2014)
8	Ireland	National	2010	The carbon tax is limited to those sectors outside of the EU ETS, as well as excluding most emissions from farming. Instead, the tax applies to petrol, heavy oil, auto-diesel, kerosene, liquid petroleum gas (LPG), fuel oil, natural gas, coal and peat, as well as aviation gasoline.	€20 per tCO_2e (2013)
9	Japan	National	2012	Japan's Tax for Climate Change Mitigation covers the use of all fossil fuels such as oil, natural gas, and coal, depending on their CO_2emissions. In particular, by using a CO_2 emission factor for each sector, the tax rate per unit quantity is set so that each tax burden is equal to US$2/$tCO_2$ (as of April 2014).	US$2 per tCO_2e (2014)
10	Mexico	National	2012	Mexico's carbon tax covers fossil fuel sales and imports by manufacturers, producers, and importers. It is not a tax on the full carbon content of fuels, but rather on the additional amount of emissions that would be generated if the fossil fuel were used instead of natural gas. Natural gas therefore is not subject to the carbon tax, though it could be in the future. The tax rate is capped at 3% of the sales price of the fuel. Companies liable to pay the tax may choose to pay the carbon tax with credits from CDM projects developed in Mexico, equivalent to the value of the credits at the time of paying the tax.	10-50 pesos per tCO_2e (2014)* * Depending on fuel type
11	Norway	National	1991	About 55% of Norway's CO2 emissions are effectively taxed. Emissions not covered by a carbon tax are included in the country's ETS, which was linked to the European ETS in 2008.	US$4-69 per tCO_2e (2014)* *Depending on fossil fuel type and usage

	Country/ jurisdiction	Type	Year adopted	Overview/coverage	Tax rate
12	South Africa	National	2016	South Africa plans to introduce a carbon tax at RND120 per tonne of CO_2e, with annual increases starting in January 2016. The tax is envisioned to be a fuel input tax based on the carbon content of the fuel and cover all stationary direct GHG emissions from both fuel combustion and non-energy industrial process emissions, amounting to approximately 80% of the total GHG emissions.	RND120/tCO_2e (Proposed tax rate for 2016)* *Tax is proposed to increase by 10% per year until end-2019
13	Sweden	National	1991	Sweden's carbon tax was predominantly introduced as part of energy sector reform, with the major taxed sectors including natural gas, gasoline, coal, light and heavy fuel oil, liquefied petroleum gas (LPG), and home heating oil. Over the years, carbon tax exemptions have increased for installations under the EU ETS, with the most recent increase in exemption starting from 2014 for district heating plants participating in the EU ETS.	US$168 per t$CO_2$e (2014)
14	Switzerland	National	2008	Switzerland's carbon tax covers all fossil fuels, unless they are used for energy. Swiss companies can be exempt from the tax if they participate in the country's ETS.	US$68 per t$CO_2$e (2014)
15	United Kingdom	National	2013	The UK's carbon price floor (CPF) is a tax on fossil fuels used to generate electricity. It came into effect in April 2013 and changed the previously existing Climate Change Levy (CCL) regime, by applying carbon price support (CPS) rates of CCL to gas, solid fuels, and liquefied petroleum gas (LPG) used in electricity generation.	US$15.75 per t$CO_2$e (2014)

Source: http://www.worldbank.org/content/dam/Worldbank/document/SDN/background-note_carbon-tax.pdf.

20 Linkage of regional, national, and sub-national policies in a future international climate agreement

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As international negotiations proceed towards COP21 in Paris in December 2015, a hybrid policy architecture is emerging under the 2011 Durban Platform for Enhanced Action, in which all countries will participate under a common legal framework. This hybrid architecture for the Paris agreement will likely feature bottom-up elements in the form of a pledge-and-review system of Intended Nationally Determined Contributions (INDCs) plus top-down elements, such as for monitoring, reporting, and verification. The INDCs will feature a broad range of targets (in keeping with the UNFCCC principle of common but differentiated responsibilities and respective capabilities) and a diverse set of national policies and actions intended to achieve those targets. Cap-and-trade has emerged as one preferred policy instrument for reducing emissions of greenhouse gases (GHGs) in much of the industrialised world, as well as within key parts of the developing world. This includes Europe, the US, China, Canada, New Zealand, and Korea. Because linkage – unilateral or bilateral recognition of allowances – can reduce compliance costs and improve market liquidity, there is considerable interest in linking cap-and-trade systems. Beyond this, many jurisdictions will propose or adopt other types of climate policies, including carbon taxes, performance standards, and technology standards. With varying degrees of difficulty, such heterogeneous policy

1 This chapter draws upon previous co-authored work, including Bodansky et al. (2014), and Ranson and Stavins (2015), but the author is responsible for any errors and all opinions expressed here.

instruments can also be linked across borders. This chapter reviews the key benefits and concerns associated with various types of linkages, and examines the role that linkage may play in the 2015 Paris agreement.

1 Introduction

The Kyoto Protocol, negotiated in 1997, has entered what is probably its final commitment period of 2013-2020, covering only a small fraction – 14% – of global GHG emissions. It is scheduled to be replaced by a new international agreement featuring a new policy architecture. In 2011, at the Seventeenth Conference of the Parties (COP17) of the United Nations Framework Convention on Climate Change (UNFCCC), the nations of the world adopted the Durban Platform for Enhanced Action, in which they agreed to develop a 'protocol, another legal instrument or an agreed outcome with legal force under the Convention applicable to all Parties' for adoption at COP21 in December 2015 in Paris (UNFCCC 2012).

It now appears likely that the Paris agreement will feature a hybrid climate policy architecture, combining top-down elements, such as for monitoring, reporting, and verification, with bottom-up elements, including 'Intended Nationally Determined Contributions' (INDCs) from each participating country describing what it intends to do to reduce emissions, starting in 2020, based on its national circumstances (Bodansky and Diringer 2014).

For such a system to be cost effective – and thus more likely to achieve significant global emissions reductions – a key feature will be linkages among regional, national, and sub-national climate policies, where 'linkage' refers to the formal recognition by a GHG mitigation programme in one jurisdiction (a regional, national, or sub-national government) of emission reductions undertaken in another jurisdiction for purposes of complying with the first jurisdiction's mitigation programme. How can the 2015 Paris agreement facilitate such linkage?

2 Diverse forms of linkage

Policy instruments in different political jurisdictions can be linked through mutual recognition and crediting for compliance. This can be between two cap-and-trade systems, between two tax systems, between cap-and-trade and tax systems, between either of those and non-market regulatory systems, or among regulatory systems (Metcalf and Weisbach 2012). Linkage can be direct or indirect, and bilateral or multilateral.

Direct linkage occurs when an agreement is reached between two systems to accept allowances (or credits) from the other jurisdiction for purposes of compliance. This can occur on a one-for-one basis – for example in the case of cap-and-trade linkage – where an allowance from one jurisdiction is accepted in place of an allowance for the same amount of emissions in another jurisdiction (Ranson and Stavins 2013, 2015), or a trading ratio (exchange rate) can apply to allowance transfers between the two systems. Direct linkage can be bilateral (two-way), where both systems accept allowances from the other system for compliance, or unilateral (Ranson and Stavins 2013).

Indirect linkage occurs when two systems do not accept allowances from each other, but both accept allowances (or credits) from a common third party (Ranson and Stavins 2013). For example, by accepting credits (or allowances) from a common source (jurisdiction), two cap-and-trade allowance markets influence the common offset market, and in turn both influence allowance prices (and compliance costs) in each other's markets.

Cap-and-trade programmes provide the most obvious example of linkage, but it is highly unlikely that all or even most countries will employ national cap-and-trade instruments as their means of reducing GHG emissions under the Paris agreement. Other possible instruments include carbon taxes or fees, emission reduction credits (ERCs), and traditional regulatory approaches.[2] Hence, it is important to consider options for linking different types of policy instruments (Hahn and Stavins 1999, Metcalf and Weisbach 2012).

2 See the chapters in this book by Sterner and Köhlin (2015) and Burtraw (2015).

For example, firms that are subject to a carbon tax could be allowed to pay taxes at a higher level than they owe based on their emissions, and sell certified 'Emission Tax Payment Credits' (ETPCs) to firms that are operating under a cap-and-trade system. Within the cap-and-trade region, firms could use ETPCs just as they would the equivalent quantity of allowances for purposes of compliance. Conversely, firms under the cap-and-trade system could sell allowances to firms required to pay a carbon tax, allowing the purchasing firm to lower its tax obligation by the amount of allowances it submits for retirement. Likewise, either a carbon tax or a cap-and-trade system could be linked with policies that provide subsidies for emissions reductions, which could be traded like ERCs to be used in place of allowances to comply with a cap-and-trade programme, or as ETPCs for compliance with a carbon tax (Metcalf and Weisbach 2012).[3]

Market-based mechanisms (taxes, targeted subsidies, and cap-and-trade) could – in principle – be linked with a conventional, performance-based regulatory system. If the regulation is in the form of a quantity standard (for example, tons of carbon-dioxide-equivalent (CO_2-e) emissions reduction), firms could buy allowances or ETPCs from another market to meet the required quantity of reduction, or to achieve reductions in excess of the regulatory minimum and then sell additional reductions as ERCs (Metcalf and Weisbach 2012).[4]

3 Potential merits

Because linkage allows for voluntary exchanges across systems, it facilitates cost-effectiveness, that is, achievement of the lowest-cost emissions reductions across the set of linked systems, minimising both the costs for individual jurisdictions as well as the overall cost of meeting a collective cap. Also, by increasing the number of allowance buyers and/or sellers across linked cap-and-trade systems, linkage tends to increase market liquidity (Ranson and Stavins 2015). And to the degree that linkage reduces

3 For example, Mexico's carbon tax allows the use of offset credits from projects under the Kyoto Protocol's Clean Development Mechanism (CDM) in lieu of tax payments (ICAP 2014).

4 Technology standards present a much greater challenge, because it is difficult to verify the additionality of emissions reductions from meeting or exceeding a technology standard.

carbon price differentials across countries or regions, it also reduces the potential for competitive distortions caused by leakage, that is, incentives for emissions-generating sources or activities to move to jurisdictions with less stringent climate policies.

Moreover, by expanding the scope and size of the market for carbon allowances, linkage can mitigate allowance price shocks caused by unexpected shocks (Burtraw et al. 2013), and thereby reduce price volatility, although in the process, linkage also can transmit price volatility from one jurisdiction to another. Finally, linkage can reduce the market power of individual market participants, provided that the same entity is not a significant allowance buyer or seller in both jurisdictions (Wiener 1999, Metcalf and Weisbach 2012).

Turing to potential political advantages, one possible political motivation for linkage is the ability of a country to demonstrate global leadership. For example, the European Commission indicated that linking the European Union's Emissions Trading System (EU ETS) with other cap-and-trade systems 'offers several potential benefits, including… supporting global cooperation on climate change' (European Commission 2014). The prospect of linkage may allow nations to exert greater diplomatic influence on unlinked, free-riding nations, encouraging them to take action on climate change. This is related to the notion of 'climate clubs' as an approach to international cooperation (Nordhaus 2015).[5]

Likewise, international linkage agreements can offer domestic political benefits, as leaders can point to linkage as a sign of 'momentum' for increasing participation in systems similar to (or at least compatible with) their domestic climate policies. There can be administrative benefits from linking that come from sharing knowledge about the design and operation of a policy instrument. For example, Quebec may benefit from

5 A frequently proposed mechanism to make benefits exclusive to the members of a climate club has been a set of national border adjustments (tariffs in countries with carbon taxes and/or import allowance requirements in countries with cap-and-trade systems); Nordhaus (2015) follows this approach. In this chapter, I emphasise fundamentally less coercive approaches to international cooperation, but in both forms of cooperation, the use of market-based policy instruments and international linkage are key.

its linkage with the larger Californian cap-and-trade system.[6] Also, linkage may reduce administrative costs through the sharing of such costs and the avoidance of duplicative services.

Political support for linkage may also come from the capture of greater local co-benefits, such as reductions of emissions of correlated pollutants (Flachsland et al. 2009). If one jurisdiction has a lower GHG price than another before linkage, linkage may provide a market for additional emissions reductions in the low-price jurisdiction that yields additional co-benefits to that jurisdiction. Conversely, a high-price jurisdiction may resist linking with a low-price system because linkage could mean fewer domestic emissions reductions, with the loss of related co-benefits. This concern was raised during debates in California regarding whether to link with Quebec's cap-and-trade system.

4 Potential problems

First, linkage has the potential to improve the cost-effectiveness of a pair of linked policies only if there is sufficient environmental integrity in both systems with respect to their monitoring, reporting, and verification requirements (Ranson and Stavins 2015). If one jurisdiction in a linked pair or large set of linked jurisdictions lacks the capacity or motivation to track emissions and emission allowances accurately, these loopholes will be exploited throughout the system, damaging the cost-effectiveness of the full set of linked policies. This can create significant barriers to linkage between nations with different levels of environmental and financial management (Metcalf and Weisbach 2012).

Linkage can undermine environmental integrity. For example, linkage can result in double counting if transfers between countries are not properly accounted for and if, as a result, the same emissions reduction is counted towards compliance in more than one national system. Of course, guarding against such errors is one of the roles for the top-down elements of the Paris policy architecture, as I discuss later.

6 For details about the California-Quebec and other existing linkages, the reader is referred to Bodansky et al. (2014) and Ranson and Stavins (2015).

Strategic behaviour could also produce adverse economic consequences in a set of linked systems (Helm 2003). In particular, if countries anticipate the possibility of future linkages, they may behave strategically when establishing their national targets. And even if a linkage is established, it may not be executed in terms of actual trades if transaction costs inhibit trading.

Turning to potential political problems of linkage, it is important to recognise that whereas linkage has the potential to improve aggregate cost-effectiveness across jurisdictions, it can also have significant distributional implications between and within jurisdictions (Ranson and Stavins 2015). Firms that were allowance buyers (firms with high abatement costs) in the jurisdiction with the higher pre-link allowance price will be better off as a result of the allowance price changes brought about by linking, as will allowance sellers (firms with low abatement costs) in the jurisdiction with the lower pre-link allowance price. Conversely, allowance sellers in the jurisdiction with the higher pre-link allowance price and allowance buyers in the jurisdiction with the lower pre-link allowance price will be hurt by the allowance price change that results from the link. For the jurisdiction that faces higher prices post-linkage, this means greater transfers from buyers to sellers (Newell et al. 2013).

An increase in the volume of trades (as a result of linkage) may also have distributional implications and attendant political consequences, depending on the relative influence of buyers and sellers in the jurisdiction (Ranson and Stavins 2015). Within jurisdictions, the potential also exists for elites in developing countries to capture allowances from domestic cap-and-trade systems and sell them into linked markets to the detriment of the local economy (Somanathan 2010).

In some cases, jurisdictions that have established emissions-reduction policies may be motivated, at least in part, by a political desire to provide incentives for long-term investment in domestic abatement activities. If a system with a high allowance price links with a system with a lower allowance price, the firms in the system with higher abatement costs will have less incentive to find innovative ways to reduce their emissions, since they can opt instead to purchase allowances at the new lower price. The result may be less technological innovation than expected under the emissions policy pre-linkage.

Finally, linkage presents the political challenge of ceding some degree of national (or other jurisdictional) autonomy. Before two jurisdictions link, they may need to agree on how to reconcile design features that they have separately established for their respective systems (Ranson and Stavins 2013). As those design features may represent a compromise between competing stakeholder interests within a country, any changes could pose political hurdles.

5 Linkage under the 2015 Paris agreement

Specific elements of a future international policy architecture under the 2015 agreement could help facilitate the growth and operation of a robust system of international linkages among regional, national, and sub-national policies. On the other hand, other potential elements of a new agreement could get in the way of effective, bottom-up linkage.

5.1 Elements that would inhibit effective linkage

One design element that would have the effect of inhibiting international linkage would be overly prescriptive or restrictive rules on allowable trading across linked systems. A clear example would be a requirement (or even a preference) for domestic actions to achieve national commitments. Such a 'supplementarity principle' can render cross-border linkage difficult or impossible, and thereby drive up compliance costs, decrease international ambition, and reduce the feasibility of reaching an agreement.

For example, several provisions of the Kyoto Protocol suggest that internal emissions abatement should take precedence over compliance through the Protocol's flexibility mechanisms (International Emissions Trading, Joint Implementation, and the CDM), but the precise meaning of this principle of supplementarity has been debated since the adoption of the Protocol.

A second issue is the confusion that can arise from competing and conflicting objectives and rules between the UNFCCC and regional or national policies. The potential for conflicting rules relates to a broader issue about how national or regional carbon mitigation systems become recognised as valid for the purposes of meeting international commitments under the Paris agreement. There are two possible approaches – approval and transparency – through which reductions under domestic systems might become eligible for counting in the UNFCCC context (Marcu 2014). The former would require explicit COP approval of domestic systems, while the latter would involve the development of model rules through COP negotiations.

A third area of potential concern stems from a lack of clarity (or even confusion) over objectives. For example, adding a 'sustainable development condition' to CDM projects can create confusion in markets. This in turn undermines trading across systems, an essential role of linkage. Finally, rules that restrict which countries can link (for example, allowing linkage only among Annex I countries), or that make it difficult for countries to join the category of countries that can link, would inhibit effective linkage.

5.2 Elements that could facilitate effective linkage

If linkage is to play a significant role in executing a hybrid international policy architecture, several categories of design elements merit consideration for inclusion in the Paris agreement, either directly or by establishing a process for subsequent international negotiations.

Effective linkage requires common definitions of key terms, particularly with respect to the units that are used for compliance purposes. This will be especially important for links between heterogeneous systems, such as between a carbon tax and a cap-and-trade system. A model rule for linkage could be particularly helpful in this area. Registries and tracking are necessary with linked systems, whether the links bring together a homogeneous or heterogeneous set of policies.

Indeed, a key role for the top-down part of a hybrid architecture that allows for international linkage of national policy instruments will be tracking, reporting, and recording allowance unit transactions. A centralised institution could maintain the accounts of parties that hold allowances, record transfers of allowances between account holders, and annually reconcile allowances and verified emissions. Some form of international compliance unit would contribute to more effective and efficient registry operation and would help avoid double-counting problems.

International compliance units would make the functioning of an international transaction log more straightforward and reduce the administrative burden of reconciling international registries with national registries. There is also a possible role for the UNFCCC to provide centralised registry services for countries that lack the capacity to develop national registries on their own. Finally, there may be economies of scale in regionalising registries for certain developing countries under the auspices of the UNFCCC or some other multilateral institution (for example, the World Bank or a regional development bank).

More broadly, any system, with or without linkage, will require monitoring, verification, and reporting of emissions (Weiner 2015). Likewise, compliance and enforcement mechanisms are of generic need in any effective agreement.

The interaction of linked systems with cost-containment elements (banking, borrowing, offsets, and price-stabilisation mechanisms) raises particular issues in the context of linkage, because in some cases these mechanisms automatically propagate from one linked system to another. Common rules for approving and measuring offsets may be important, and – more broadly – a tiered system of offset categories could be helpful, with jurisdictions choosing their own 'exchange rates' for each category.

Finally, market oversight and monitoring, together with various safeguards against market manipulation such as by large holders of allowances who may be able to exercise market power, may increase confidence in the system. In some cases, national and international institutions may already exist, or need only relatively minor additional capacity, to provide these functions.

6 Conclusion

The 2015 Paris agreement will likely be a critical step in the ongoing international process to reduce global GHG emissions. Whether the agreement is judged to be sufficiently ambitious remains to be seen. In general, greater ambition is more easily realised when costs are low. Linkage — between and among market and non-market systems for reducing GHG emissions — can be an important element in lowering costs.

If linkage is to play a significant role, then several categories of design elements merit serious consideration for inclusion in the Paris agreement. However, including detailed linkage rules in the core Paris agreement is not desirable as this could make it difficult for rules to evolve in light of experience. Instead, minimum standards to ensure environmental integrity should be elaborated in COP decisions – for example, the COP could establish minimum requirements for national measuring, reporting and verification (MRV), registries, and crediting mechanisms. In terms of linkage, the function of the core Paris agreement might be confined to articulating general principles relating to environmental integrity, while also authorising the COP or another organisation to develop more detailed rules.

Ultimately, the most valuable outcome of the Paris agreement regarding linkage might simply be the inclusion of an explicit statement that parties may transfer portions of their INDCs to other parties and that these transferred units may be used by the transferees to meet INDCs. Such a statement would help provide certainty both to governments and private market participants and is likely a necessary condition for widespread linkage to occur. Such a minimalist approach will allow diverse forms of linkage to arise among what will inevitably be heterogeneous INDCs, thereby advancing the dual objectives of cost-effectiveness and environmental integrity in the international climate policy regime.

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21 Options for avoiding carbon leakage

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Carbon leakage – the increase in foreign emissions that results as a consequence of domestic actions to reduce emissions – is of particular concern for countries seeking to put a substantial price on carbon ahead of their trading partners. While energy market reactions to changes in global fossil fuel demand are difficult to avoid, absent a global price on carbon, some options are available to address leakage associated with changes in competitiveness of energy-intensive, trade-exposed industries. This chapter discusses the main legal and economic trade-offs regarding the use of exemptions, output-based rebating, border carbon adjustment, and sectoral agreements. The potential for clean technology policies to address the energy market channel is also considered.

Ultimately, unilateral policies have only unilateral options for addressing carbon leakage, resulting in weak carbon prices, a reluctance to go first and, for those willing to forge ahead, an excessive reliance on regulatory options that in the long run are much more costly means of reducing emissions than carbon pricing. Recognising those costs, if enough major economies could agree on a coordinated approach to carbon pricing that spreads coverage broadly enough, carbon leakage would become less important an issue. Furthermore, a multilateral approach to anti-leakage measures can better ensure they are in harmony with other international agreements. If anti-leakage measures can support enough adherence to ambitious emissions reduction programmes, they can contribute to their own obsolescence.

1 Introduction

Carbon leakage is a chief concern for governments seeking to implement ambitious emissions reduction policies – particularly those that place high prices on carbon – ahead of similar actions on the part of their major trading partners. 'Emissions leakage' is generally defined as the increase in foreign emissions that results as a consequence of domestic actions to reduce emissions. Since greenhouse gases (GHGs) are global pollutants, emissions leakage in the case of carbon is a particular concern, as it directly undermines the benefits of the domestic emissions reductions.

Carbon leakage from economy-wide carbon pricing policies in major economies is centrally estimated by global trade models to range between 5% and 30%.[1] Higher rates are associated with smaller coalitions, higher carbon prices, more substitution through trade, and stronger energy market responses. Sector-specific carbon leakage rates can be much higher, as well – as much as three to five times the economy-wide leakage rate.[2]

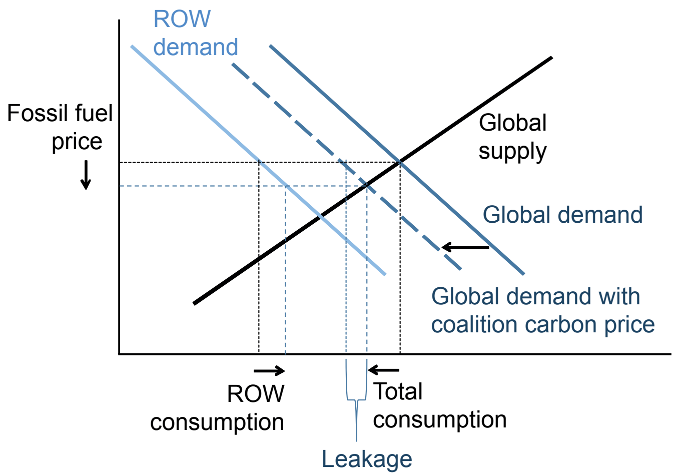
Carbon leakage occurs through multiple channels. The largest one, as indicated by the modelling literature, is the *energy market channel*. The idea is that if a major economy on its own withdraws a lot of demand for fossil fuels, the global prices for those fuels become depressed. As a consequence of cheaper prices, other countries consume more fossil fuels and their economies become more carbon intensive.

Figure 1 illustrates this form of carbon leakage with global supply and demand curves for fossil fuels. If a coalition of countries adopts carbon pricing, their demand (and thus global demand) for fossil fuels shifts inward. If the price did not change, the quantity that suppliers offer would exceed the quantity demanded at that price; thus, the price falls to find a new market equilibrium. However, since demand in the rest of the world (ROW) has not changed, they consume more at the new lower price. Therefore, the net reduction in global consumption is less than the reduction in coalition consumption.

1 Readers interested in more detail can see an Energy Modeling Forum exercise on carbon leakage and border carbon adjustments (EMF 29), published as a Special Issue of *Energy Economics* (Böhringer et al. 2012).

2 Fischer and Fox (2012).

Figure 1 Carbon leakage from demand and supply responses in energy markets



The reasoning is the same as many explanations for the drop in oil prices and their consequences over the past year: growth in worldwide demand has been lower than expected, and now lower gasoline prices are encouraging more sales of SUVs, which have higher fuel consumption rates. Importantly, the energy market channel operates via any changes in demand for fossil fuels, whether due to carbon pricing or regulation and energy efficiency.

The channel for carbon leakage that causes the greatest concern for policymakers, however, is the *'competitiveness' channel*. This channel relates to policies – like carbon pricing – that pass on higher energy costs to energy-intensive, trade-exposed (EITE) industries, making manufacturing in carbon-pricing countries less competitive. This causes economic activity, market share, and, in the longer run, investments in those sectors to shift abroad to jurisdictions with lower energy costs. Modelling results indicate that one-quarter to one-half of carbon leakage occurs through competitiveness effects. This channel is somewhat narrower than the energy market channel, as it primarily affects specific industrial sectors that represent a small share of the economy,[3] but they have outsized effects on emissions leakage, and may also wield outsized political influence.

3 In the case of the US, industries with energy expenditures in excess of 5% of the value of their output account for only one-tenth of the value of US manufacturing output and less than 2% of US GDP (Fischer et al. 2014).

A third channel, the *induced innovation channel*, has the potential to create negative leakage in the long term. If carbon mitigation policies induce innovation in clean energy technologies, lowering their costs globally, all countries will find them more attractive. Greater adoption of clean technologies in countries with low or no carbon prices will help displace fossil fuels and further reduce global emissions. On the other hand, countries with low carbon prices that become more competitive in energy-intensive sectors may see their technical change directed towards energy-using technologies, exacerbating carbon leakage. Thus far, this innovation channel has been theorised (e.g. Gerlagh and Kuik 2014) but empirical evidence of its scope is lacking.

1.1 Carbon pricing and carbon leakage

Understanding these different channels informs how we evaluate the options for addressing carbon leakage. Clearly, the best option for reducing emissions while addressing all channels of leakage would be to have harmonised carbon prices worldwide. Of course, this is not a likely outcome of the current framework for INDCs, although such commitments would certainly not be precluded. Several prominent economists are advocating for forming a club of major economies with minimum carbon prices (see, for example, Nordhaus 2015, Gollier and Tirole 2015, Weitzman 2013).

The challenge is that options for dealing with carbon leakage unilaterally are more limited. One, unfortunately, is simply to set lower carbon prices – that creates less pressure for leakage, but also less incentive for emissions reductions. Arguably, we observe a fair amount of this behaviour. Currently, about 12% or less of global CO_2 emissions is subject to a carbon price (World Bank 2015). With the exception of some carbon taxes in Scandinavian countries, current prices are well below $40 – the US Environmental Protection Agency's central estimate of the global social cost of carbon (SCC) – and all of the largest systems have prices below $15 (see also the contribution by Wang and Murisic in this book).[4]

One reason for individual jurisdictions to contribute too little to the global public good of climate mitigation is the free-rider effect: most of the benefits accrue to other

4 Prices as of 1 April 2015: California $13, EU ETS $8, RGGI $6, Japan carbon tax $2, Chinese provincial pilot ETS $5-8. (World Bank 2015).

jurisdictions, and those benefits can be enjoyed whether or not one contributes oneself. These types of incentives create challenges for an international climate agreement. However, many climate negotiators may take issue with the idea that their countries are seeking to free ride on the efforts of others. Indeed, many feel an ethical responsibility to contribute significant emissions reduction programmes, but not by using significant carbon prices when their trade partners are not facing similar policies. The US is an example – in its regulatory policy evaluations, it uses a global SCC, not a domestic (self-interested) SCC as one would expect of a free-rider. However, its main contributions involve regulatory standards for power plant emissions and vehicles, but not carbon pricing (see the chapter by Burtraw in this book). Thus, while free-riding would weaken intentions to take action, the fear of carbon leakage weakens the actions of the well-intentioned, thereby exacerbating the challenge of a strong international agreement on emissions mitigation.

Still, there are some other options that countries or clubs of countries might take to address carbon leakage unilaterally. Most of the commonly proposed options are only suited for addressing competitiveness-related leakage.

2 Addressing the competitiveness channel

Mitigating the leakage associated with the competitiveness channel has the additional benefit of addressing the competitiveness concerns that often create barriers to putting a price on carbon. Indeed, if carbon pricing is not possible in a domestic context in the absence of dealing with competitiveness-related leakage, then these measures can be argued to have a much bigger impact on global emissions reductions than just the leakage avoided. However, one must tread carefully, as competitiveness concerns are related to international trade, and trade-related measures are governed by disciplines agreed to in the WTO, as explained by Mavroidis and de Melo in their chapter in this book. Moreover, many of the EITE industries of concern are already experiencing dislocation and pressures through changes in international trade patterns, so it can be difficult to distinguish motivations for dealing with emissions leakage from baser motivations to protect domestic industries. Hence, it is important to consider these options in tandem with the potential constraints imposed by international trade law.

Firms face two kinds of cost increases from emissions-reduction policies. One is higher production costs associated with reducing emissions – that is, the changes in techniques or equipment that require less energy, emissions, or emissions-intensive inputs. These costs occur whether the changes are being directed by regulation or by price incentives. A second cost increase is associated only with carbon-pricing mechanisms, which require firms to pay for their embodied emissions (that is, the emissions remaining after reduction efforts, associated with their production), either by paying a carbon tax or by surrendering valuable emissions allowances. Generally, it is only these embodied carbon costs that can be addressed in a straightforward and transparent manner, in accordance with other legal obligations.

Anti-leakage policies for the competitiveness channel focus directly on the EITE sectors. In all cases, some determination of eligibility must be made. In order to buttress an argument that the measures are being undertaken for the purposes of avoiding leakage, the criteria for eligibility must be clearly related to leakage potential – that is, involving a combination of carbon-intensiveness of manufacturing and trade exposure. At that point, there are three main options for addressing leakage among identified EITE sectors: exemption from carbon pricing, output-based rebating, and border carbon adjustments.

2.1 Exemptions

A straightforward option is to exempt qualified EITE industries from the broader GHG reduction policy, in whole or in part. For example, in Sweden, industrial consumers pay no energy tax and only 50% of the general carbon tax; in Germany, heavy industry is exempt from the surcharges for renewable energy and EITE sectors can request exemptions from most energy taxes. While potentially simple from an administrative point of view, exemptions tend to be a highly inefficient means of addressing emissions leakage. By differentiating carbon prices among industries, some cost-effective options for reducing emissions will be left untapped, which will either limit overall reductions or leave a greater burden on the remaining non-exempt industries. As a result, exemptions would likely increase the total cost of achieving a given emissions target, unless leakage effects are very strong (and the alternative would be weakening the carbon price for all). Furthermore, exemptions do not address indirect emissions; for example, certain sectors like aluminium may see larger competitiveness impacts from the pricing of carbon in electricity than from their direct emissions.[5]

Exemptions are not terribly likely to be seen as a trade-related measure, as the coverage of an emissions trading system or the designation of a carbon tax base is typically viewed as an intrinsic policy decision. However, in some interpretations, they could be viewed as subsidies.

2.2 Output-based rebating (OBR)

A second, common option is to use rebates to relieve some, or all, of the burden from the price on embodied carbon. The idea is to keep all energy-intensive industry under the carbon-pricing system, but to offer rebates for the EITE sectors in proportion to their output, based on a benchmark of sector-wide performance. For example, the EU chose a benchmark of the performance of the top 10% of firms (i.e. those with lowest emissions intensities) in a sector, while New Zealand uses up to 90% of average emissions intensity, based on recent historical data. Since more output generates more rebates, the rebate functions like a subsidy to output of EITE firms, signalling that emissions reductions should not be sought through reductions in output (since that would result in leakage). The advantage relative to exemptions is that OBR retains the carbon price incentive to reduce emissions intensity. However, it does come at a cost of muting the carbon price signal passed on to consumers, who then have less incentive to consume less energy-intensive products or find cleaner alternatives.

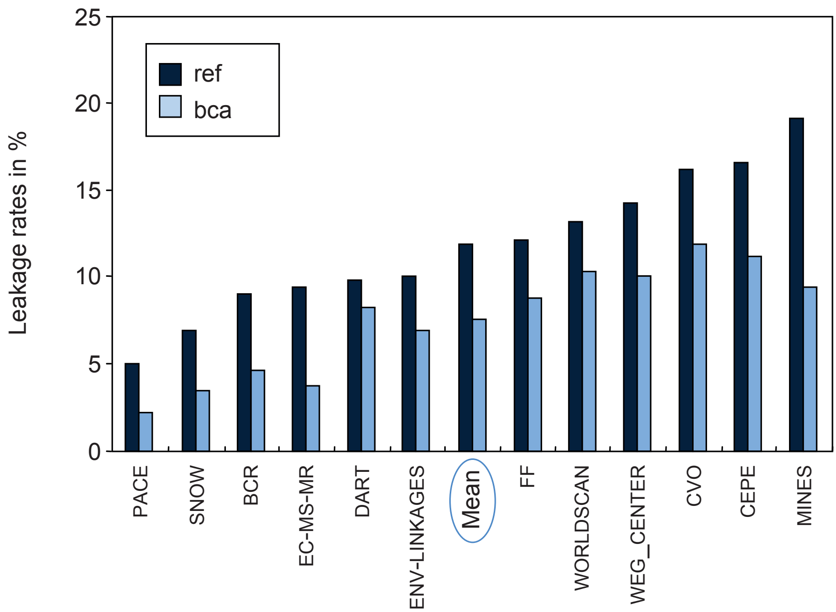
Preferential allocations or rebates to specific industries can, in theory, also be challenged as subsidies under trade rules. However, such a case has yet to be made in the WTO context, perhaps since to date such rebates have been implemented in domestic regulatory mechanisms (cap-and-trade programmes) with benchmarks that still imply some net tax burden on embodied emissions (Mavroidis and de Melo 2015).

5 Of the GHGs from global aluminium production unrelated to transport, electricity accounts for 62% of emissions, nearly twice that of direct process and thermal energy emissions (World Aluminium 2014).

2.3 Border carbon adjustment (BCA)

The third option is border carbon adjustment (BCA) of a domestic carbon price, which would levy charges on imports of EITE products to ensure that consumers pay the same price for embodied carbon, regardless of the origin. A recent Energy Modelling Forum modelling exercise on carbon leakage (summarised in Böhringer et al. 2012) found that BCA for EITE sectors for reduced carbon leakage from actions taken by OECD countries by one quarter to one half across most models (Figure 2).

Figure 2 Model estimates of leakage rates from OECD coalition carbon pricing (%)



Note: Vertical axis lists participating models by name. The dark blue bars represent simulated leakage rates in the reference scenario (OECD countries implementing emissions pricing to achieve global reductions equal to 20% of their baseline emissions). The light blue bars represent simulated leakage rates with the addition of BCA for EITE industries.

Source: Böhringer et al. (2012).

While theory and modelling tend to show that BCA is the most cost-effective option for addressing leakage, they also point to considerable tensions in design trade-offs. Furthermore, as an overtly trade-related measure, BCA is likely to raise disputes in trade circles, although a consensus has developed among international trade lawyers that they could be designed in accordance to WTO law. The key cases to be made are that the measure meets the WTO requirements for an Article XX exception – that is, it is essential and effective for reducing leakage – and that it conforms to the principle of common but differentiated responsibilities (CBDR) under international environmental law. Cosbey and Fischer (2014) and Cosbey et al. (2015) enumerate a full range of issues in designing a BCA regime that meets these goals, of which a few critical ones are highlighted here.

At its logical limit, if BCA were applied to all products, it would convert the carbon-pricing regime from one that taxes carbon arising from production to one that taxes carbon embodied in consumption (much like a value-added tax is a destination-based tax). While calling on consumers in developed countries to take responsibility for their carbon consumption sounds appealing, full BCA causes a strong shift in the terms of trade to the detriment of developing countries. For example, China's exports are eight times as carbon-intensive as those of the EU and three times those of the US (Atkinson et al. 2011). However, most of the avoided leakage benefits come from BCAs in the EITE sectors, and limiting the application of the measure to those sectors has less of a burden-shifting effect, supporting CBDR, as well as a stronger link to the legal motivations for an Article XX exception (Cosbey and Fischer 2014; Cosbey et al. 2015).

Another tension involves the use of the revenues collected at the border. Returning revenues to the exporting countries further mitigates the burden-shifting effects and can show good faith that the policy is being implemented for leakage rather than protectionist purposes. Another option conforming to these goals would be to earmark the revenues towards the financing of mitigation and adaptation activities in developing countries. On the other hand, larger burden-shifting effects make it more attractive for countries to be inside, rather than outside, the club of countries pricing carbon and imposing BCAs.

International legal obligations thus make it difficult to use BCAs to create leverage for getting other countries to take climate actions, although that would arguably have the greatest effect on limiting leakage. Some leading economists (e.g. Nordhaus 2015) have proposed using trade sanctions to enforce an agreement for high carbon prices among a club of countries; parties can always agree to a sanctions regime, but non-parties have not agreed to such measures. As a result, any sanctions against non-parties would need to meet the Article XX exception, which is likely to be limited to conforming BCAs. Unfortunately, for many countries, that may not be sufficient to ensure participation.

Some of the mundane practicalities of BCA are similar to OBR, requiring eligibility determinations for the products facing adjustment, and an exercise to calculate the embodied carbon emissions. The difference is that more accurate calculations would require foreign data, which is harder to obtain. Relying on domestic benchmarks is simpler and arguably less discriminatory (treating imported products the same as domestic counterparts), but gives blunter price signals to domestic consumers and foreign manufacturers. In addition, foreign carbon taxes paid should be taken into account, and any preferential treatment afforded domestic producers (such as rebates) must also be afforded imports. Again, a blunter instrument of exempting products from certain countries could recognise climate actions being taken, or least-developed status.

Overall, the design issues for this instrument are more complex and controversial; many experts think BCAs are likely still feasible (e.g. Cosbey et al. 2015, Mavroidis and de Melo 2015), though not all (e.g. Moore 2011, cited in Mathys and de Melo 2011). Many of the simplifications needed for administrative practicality and WTO compliance would mute some of the anti-leakage effects that one might achieve in theory with perfect information; however, the aforementioned alternatives to BCAs offer even blunter and weaker price signals for consumers. BCAs have some precedents: California has in effect BCA-like measures to discourage resource shuffling to out-of-state electricity generators. The latest carbon tax proposal in the US Senate includes a BCA. The failed attempt by the EU to include international aviation in the ETS offers a cautionary tale for BCA. A unilateral BCA measure will undoubtedly face resistance; to be accepted, BCA guidelines will have to arise out of some multilateral consensus.

2.4 Sectoral agreements

A final option for dealing with competitiveness-related leakage cannot be implemented unilaterally, but can achieve many of the goals. That would be to negotiate an agreement among major EITE trading partners for common actions to reduce emissions in those sectors. The actions may or may not be carbon pricing, but would alleviate competitiveness concerns and allow for greater emissions reductions in those sectors than simple exemptions from economy-wide carbon regulations.

3 Addressing the energy channel

While there are several options for addressing competitiveness-related leakage, there are few realistic unilateral options for addressing leakage related to global energy market adjustments. The available measures would have to either (1) raise global energy prices, or (2) lower clean energy prices.

3.1 Raising global energy prices

Raising global energy prices requires withdrawing more fossil fuel supplies than demand for them. For example, major energy producers could raise royalty payments, reduce their production subsidies, or simply commit to not extract unconventional resources. Few observers expect such commitments unilaterally.

Carbon capture and sequestration (CCS) presents another option. Incentivising or requiring the use of CCS as part of a domestic climate policy sustains demand for fossil fuels, avoiding leakage abroad, while ensuring reductions at home. However, CCS is still a relatively expensive mitigation option, and likely to remain so for the foreseeable future (see Tavoni 2015).

3.2 Lowering clean energy prices

Lowering the cost of clean energy technologies has the potential to offset the allure of cheaper fossil energy prices. However, these cost reductions must be global, and it must be noted that for the same emissions reductions, they must also be much bigger than if common carbon pricing were helping to make clean technologies competitive.

Technology policies are a popular option, particularly relative to carbon pricing; for example, over 50 countries have financial incentives or public procurement for renewable generation, and many more have feed-in tariffs or mandates.[6] The question is how well measures perform in lowering global costs. Toward this end, we may need to

6 See http://www.iea.org/policiesandmeasures/renewableenergy/ and http://www.map.ren21.net/ (accessed 1 June 2015).

distinguish between upstream incentives for manufacturers and downstream incentives for domestic deployment (see also Fischer et al. forthcoming).

Upstream measures encourage R&D and support domestic production of clean technologies. They shift out total supply, which lowers global technology prices, spurring additional deployment both at home and abroad and reducing leakage. They also benefit domestic producers at the expense of foreign ones, and may be constrained by WTO disciplines.

The effect of downstream measures depends on how global supply responds. In the short run, they shift out global demand for clean technology, which tends to bid up global equipment prices. Thus, expanded clean energy deployment at home can crowd out deployment abroad and exacerbate leakage. In the long run, however, strong learning-by-doing, complementary innovation, or scale effects may bend the global supply curve downward. In that case, both upstream and downstream policies – anything that increases clean energy scale – can lower global prices and crowd in cleaner technologies abroad. The potential for these effects is important to understand; recent work indicates that the global benefits of negative leakage from subsidies to manufacturing that lower the costs of clean technologies to all countries may be much larger than the trade-distorting effects of preferential upstream subsidies (Fischer 2015). As renewable energy subsidies are becoming contentious in the WTO, the time seems ripe for serious discussion about whether the Subsidies Code needs to make room for some clearly defined environmental exceptions to those disciplines, which are currently lacking (see the chapter by Mavroidis and de Melo in this book).

4 Conclusion

Addressing carbon leakage is a priority for supporting concerted action for mitigation, and in particular for supporting levels of carbon pricing that resembles the global social cost of carbon. In the current framework of countries individually contributing INDCs, convergence to multilateral carbon pricing will be a long time coming. With unilateral policy determinations, we are left with unilateral options for addressing carbon leakage, resulting in weak carbon prices, a reluctance to go first and, for those willing to forge ahead, an excessive reliance on regulatory options that in the long run are much more costly means of reducing emissions than carbon pricing.

Perhaps recognising those costs – not only the costs of climate change, but the costs of delayed action and the costs of second-best approaches to mitigation – enough major economies can agree on a coordinated approach to carbon pricing that spreads coverage broadly enough that carbon leakage becomes less important an issue. Furthermore, a multilateral approach to anti-leakage measures can better ensure they are in harmony with other international agreements. Ultimately, if anti-leakage measures can support enough adherence to ambitious emissions reduction programmes, they can contribute to their own obsolescence.

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