

Carbon Markets 15 Years after Kyoto: Lessons Learned, New Challenges

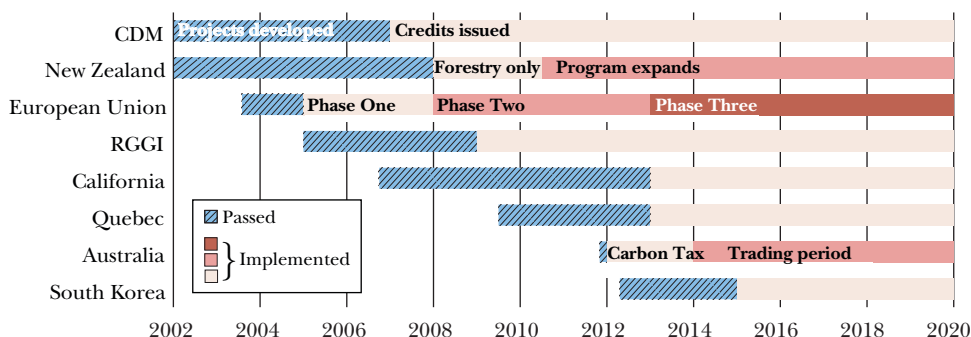
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Back in 1997, when 37 industrialized countries and the European Community committed themselves to reducing emissions of carbon dioxide and other greenhouse gases as part of the Kyoto Protocol, the public debate focused largely on how to design a single global market for trading carbon permits as “the” vehicle to address global climate change. Because one ton of a greenhouse gas emitted anywhere in the world has the same climate change consequences for everyone, a single global market would be an economically desirable outcome, equalizing incentives to reduce emissions everywhere. However, this late-1990s dream of a top-down global design now seems far away, if not impossible.

Instead, we see a multiplicity of regional, national, and even subnational markets emerging, most notably the Emissions Trading System set up by the European Union in 2005, but also including the Regional Greenhouse Gas Initiative in the northeastern United States, the New Zealand Emissions Trading Scheme, and (on the horizon) California, Quebec, Australia, and South Korea, as shown in Figure 1.

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Figure 1

Timeline for Selected Greenhouse Gas Emissions Trading Programs

Source: Authors.

Notes: “CDM” stands for the Clean Development Mechanism, which was set up as part of the Kyoto Protocol. “RGGI” stands for the Regional Greenhouse Gas Initiative, which operates in the northeastern United States.

The Clean Development Mechanism, set up as part of the Kyoto Protocol, has its own significant market for certified emission reductions undertaken by developing countries that can be used for compliance in other programs.

Thus, unlike back in 1997, we now have experience with actual carbon markets. Carbon markets are now the largest class of environmental or emissions trading markets in the world, in terms of both volume and market value, by a very wide margin. (Although other greenhouse gases may be included, we use the term “carbon market” because carbon dioxide is the dominant gas in terms of its overall contribution to global warming and because the units of trade are always denominated in terms of “carbon dioxide equivalent.”)

This turn of events raises interesting questions of why the Kyoto model has not panned out, and why a growing number of jurisdictions nonetheless continue to pursue emission reductions in the absence of an agreement among all major emitters to reduce emissions. We will not try to answer those questions here, but we direct interested readers to work by Aldy and Stavins (2007) on international climate architectures, and Victor (2008) and Nordhaus and Boyer (1998) on problems with the Kyoto approach. Instead, we want to focus on what we have learned about the design and operation of carbon markets, and what new challenges we face.

In the next section, we begin with an overview of the major existing carbon markets (along with several incipient markets) and some of their key design features. With this background in place, we then spell out a number of lessons gleaned from the functioning of these markets—lessons about the reductions in carbon emissions; effects on end-users of energy; the risk of “leakage” of carbon emissions to jurisdictions not included in the carbon market; reducing the risks of overly high or volatile prices for carbon allowances; the role for banking of emissions credits; the

role for “offsets,” which reduce emissions among unregulated sources; and the role for government regulatory oversight of these new financial markets.

The growth of a multiplicity of carbon trading programs has also raised questions that were not fully anticipated or understood during the design stages of existing carbon market systems. Now that these separate carbon markets exist, how might they be linked? How should carbon markets address the inevitable need for occasional changes in the underlying government-set rules? As countries approach carbon abatement with a mixture of different policy tools—an emission trading program, an emission tax, a performance standard, or traditional regulation—how can the overall intensity of different countries’ abatement efforts be compared? In the decentralized, bottom-up carbon market and climate policy landscape that is emerging, how can international negotiations best contribute to further progress?

The importance of understanding the strengths and weaknesses of carbon markets as they emerge is enormous, in both environmental and economic terms. Carbon dioxide is a fundamental product of the combustion of fossil fuels, and fossil fuels are the source for over 80 percent of US and global energy consumption. More than 30 billion metric tons of carbon dioxide per year are emitted globally from fossil fuel combustion (Boden, Marland, and Andres 2011). The market value of one year of allowances for these emissions at \$10 per ton of carbon, for example, would be \$300 billion; at \$25 per ton it would be \$750 billion.¹ For higher allowance prices, or aggregating across several vintages of allowances, the potential value of these hypothetical allowances is easily in the trillions of dollars. Whether these numbers are taken to represent the value of the environmental impact of carbon dioxide emissions or the potential shifts in wealth as those emissions are constrained and property rights conveyed, the numbers are large. Moreover, the lessons from carbon markets could be relevant elsewhere as market mechanisms are applied to tackle other environmental and nonenvironmental problems.

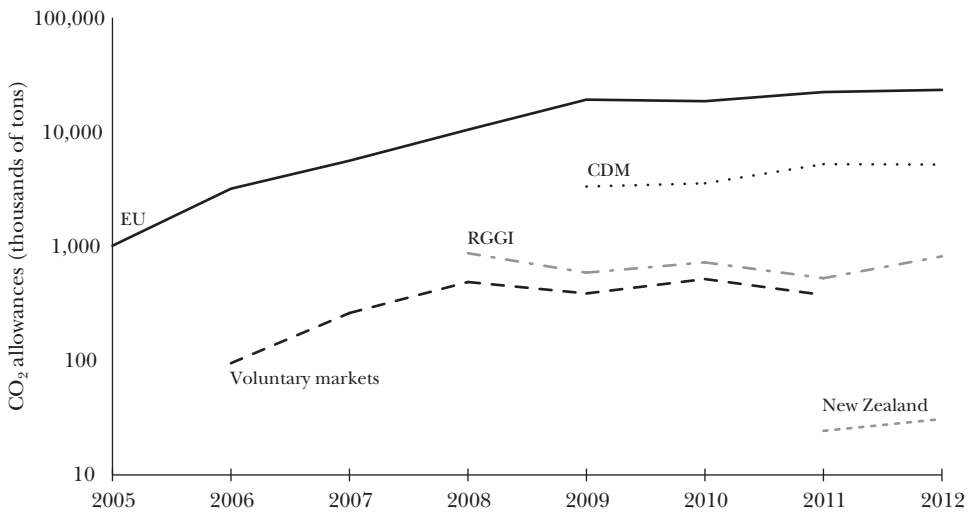
The Current Status of Carbon Markets and Some Key Design Choices

As of the end of 2012, the vast majority of carbon markets around the world took place in five arenas (each of which will be discussed below): the European Union’s Emissions Trading System (ETS); the Clean Development Mechanism (developed under the Kyoto Protocol); the Regional Greenhouse Gas Initiative (northeastern United States); New Zealand’s Emissions Trading Scheme; and voluntary markets.

The volume of trades in these markets is shown in Figure 2. The vertical axis showing the volume of trades is a logarithmic scale, and the figure demonstrates that the European Union’s Emissions Trading System (ETS) has to this point

¹ It would take us far afield to discuss climate change impacts and the many challenges of measuring mitigation benefits, but recent estimates by the US government suggesting a net present value of expected global benefits of roughly \$25 per ton of carbon dioxide reduced provide a useful reference point (Interagency Working Group on Social Cost of Carbon 2009).

Figure 2
Volume of CO₂ Allowance Trades
(daily average)



Source: Authors.

Notes: As of the end of 2012, the vast majority of carbon markets around the world took place in five arenas: the European Union's Emissions Trading System; the Clean Development Mechanism (developed under the Kyoto Protocol); the Regional Greenhouse Gas Initiative (northeastern United States); New Zealand's Emissions Trading Scheme; and voluntary markets. The volume of trades in these markets is shown in the figure. Exchange-traded volumes are through June 30, 2012 as reported by Point Carbon (<http://www.pointcarbon.com/>), RGGI CO₂ Auction Tracking System (<https://rggi-coats.org/eats/rggi/>), Ecosystem Marketplace/Bloomberg New Energy Finance (http://www.ecosystemmarketplace.com/pages/dynamic/our_publications.landing_page.php). Our voluntary market data is based on year-end reports, and thus we have no data for 2012.

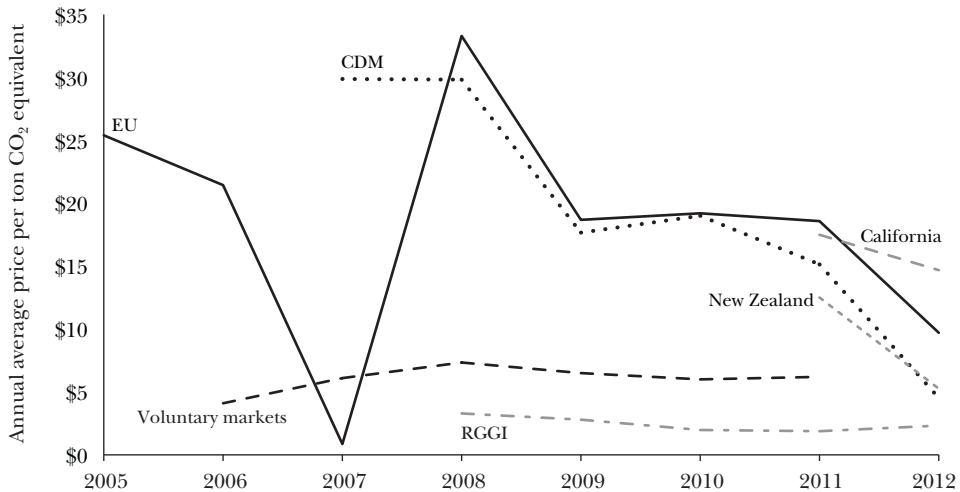
dominated the marketplace, with far greater volumes and liquidity than any other market. Volumes have been increasing, both in terms of activity within markets as well as the creation of new markets.

The average annual price per ton of carbon dioxide is shown in Figure 3. Carbon prices in all markets have been falling since 2008 in response to the global recession. Figure 3 also includes information on futures contracts in California (whose first compliance period begins in 2013). The following discussion provides an overview of major carbon markets and mentions other carbon trading programs that are scheduled to begin operating in the next year or so; for more details on other proposed and existing programs, Hood (2010) is a useful starting point.

European Union Emissions Trading System

The European Union has created by far the world's largest market-based system to reduce greenhouse gas emissions: the Emissions Trading System, which began operating in 2005 (total emissions under the cap were roughly 2.1 billion

Figure 3
CO₂ Allowance Prices
 (nominal)



Source: Authors.

Notes: “CDM” stands for the Clean Development Mechanism, which was set up as part of the Kyoto Protocol. “RGGI” stands for the Regional Greenhouse Gas Initiative, which operates in the northeastern United States. Exchange-traded prices are through June 30, 2012 as reported by Point Carbon, RGGI COATS, Ecosystem Marketplace/Bloomberg New Energy Finance. Our voluntary market data is based on year-end reports, and thus we have no data for 2012.

metric tons in 2011). The program has operated in phases, with a pilot phase from 2005–2007 covering the power sector and certain heavy industry, a second phase from 2008–2012 expanding coverage slightly, and a third phase set for 2013–2020 that will add a significant range of industrial activity. Under the first two phases, each of 27 EU nations (later expanded to include Norway, Iceland, and Liechtenstein) submitted National Allocation Plans for total emissions of greenhouse gases to the European Commission. Once the plans were finalized, nations had significant discretion over how to distribute emissions credits to different sectors of their economies (Ellerman, Convery, and de Perthuis 2010; European Commission 2012a).

The pilot phase from 2005–2007 was something of a test. Modest emissions reduction goals were enacted, but the primary goal of the pilot phase was to prepare for 2008, when the program would help the EU comply with its obligations under the Kyoto Protocol. The vast majority of allowances were allocated free of charge in the pilot and second phases, and each nation determined the level and distribution of free allocation to different sectors of the economy. These national-level plans also specified the number of offset credits emitters in each nation could purchase from carbon abatement projects in developing economies through the Clean Development Mechanism (discussed in the next section), with limits ranging from 0–20 percent of each firm’s eventual compliance obligation.

Additionally, the European system is the only one where a significant secondary market for carbon has developed, with market participants buying and selling standardized contracts up to five years in advance on a variety of exchanges. While trading in the European system began mostly with nonstandardized over-the-counter transactions, exchange-based trading likely surpassed over-the-counter volumes sometime in 2008, indicating increased levels of standardization and liquidity (Ellerman, Convery, and de Perthuis 2010).

The European Union system has evolved in a number of important ways as it enters its third phase in 2013. First, rules for distributing allowances have become more harmonized across the EU, with national-level plans now being largely a thing of the past. Second, the program has expanded to cover additional sectors of the economy, such as aviation and petrochemicals, along with additional greenhouse gases, such as nitrous oxide from certain industrial activities.

Probably the biggest hiccup for the Emissions Trading System to this point is visible in the price data in Figure 3: namely, in 2007 the price of carbon emissions collapsed to essentially zero. This situation was created by a confluence of several factors. First, the goals for emission reduction in the pilot program were constructed under time pressure with a shortage of reliable data and were supposed to be relatively modest (Ellerman, Convery, and de Perthuis 2010). Second, aggregate emission data was unavailable until almost halfway through the pilot program, and when the first tranche of actual emissions data was released in 2006 by the EU Commission, market participants realized aggregate emission levels were low vis-à-vis allowance supply. Third, emissions allowances in this pilot first phase of the program could only be used between 2005 and 2007 and could not be further banked. The too-late realization of oversupply coupled with an inability to use excess allowances sparked a dramatic fall in prices. The rationale for not allowing banking was the desire to separate Phase II (which coincided with the first Kyoto compliance period starting in 2008) from the pilot program period—but the consequences of this decision were clear: by the final quarter of 2007, spot prices were essentially zero, at €0.06/ton, even while contract futures prices for Phase II allowances hovered above €20/ton (Point Carbon 2012). Banking is now allowed in all current and future phases.

The Clean Development Mechanism

The Clean Development Mechanism (CDM) is not a cap-and-trade program, per se, but a vehicle for translating emissions reduction efforts in developing countries into credits that can be used to offset capped emissions elsewhere. In 2011, roughly 300 million tons of offsets were issued under the CDM. The CDM was created as part of the 1997 Kyoto Protocol in order to provide additional flexibility for industrialized countries to meet their specified targets (United Nations Framework Convention on Climate Change 2012b). Credits generated through the CDM, called Certified Emission Reductions, now represent the second-largest market of carbon-denominated assets and are being used as offsets in a variety of jurisdictions. (A related but smaller program called Joint Implementation was created

for emission reduction projects in the former Soviet Union and Eastern Europe. Discussions of CDM sometimes include this program as well.)

The number of proposed and implemented Clean Development Mechanism projects has grown substantially over the past five years. Over 6,200 CDM projects have been approved and more than 1 billion offset credits have been issued (authors' analysis of data from CDM/JI Pipeline, <http://cdmpipeline.org>). The distribution of offset credits was slanted heavily in early years towards a small number of projects that reduce industrial gases with massive global warming effects. (This focus turned out to be problematic, an issue we discuss in our "lessons" section.) The distribution of projects overall has been led by renewable energy such as wind, solar, or biomass, a trend that has only increased in recent years. As the industrial gas projects with large numbers of credits per project have become more limited, most credits are now issued for renewable energy, energy efficiency, and projects that capture fugitive methane emissions from landfills and other locations. However, the winding down of these high-volume industrial gas projects has also led to a decline in overall issuance of CDM credits since 2007 even as the volume of projects continues to rise.

The European Union Emissions Trading System has been the main purchaser of Clean Development Mechanism credits. Their use, however, is limited by regulations to a fraction of each member state's cap (and, in turn, the compliance obligations of each facility). In aggregate, use of Certified Emissions Reduction credits for compliance across all EU nations from 2008 through mid 2012 was roughly 6 percent of their total compliance obligation (based on the authors' analysis of data from European Environment Agency, at <http://www.eea.europa.eu/data-and-maps/data/data-viewers/emissions-trading-viewer>). In New Zealand, emitters purchase CDM credits for up to 100 percent of their compliance obligation, and in Australia, the relevant figure is 12.5 percent (with up to another 50 percent coming from domestic offset programs). In Japan, the government has purchased over 100 million CDM credits to reach its target under the first round of the Kyoto Protocol; collectively, governments are expected to purchase roughly one-third of total CDM credits through 2012 (World Bank 2012). The CDM's projects and rules continue to evolve. Currently, a variety of project types face review from the UN body overseeing the CDM as well as the European Union, which does not accept CDM credits generated from certain project types.

Regional Greenhouse Gas Initiative

In 2005, seven northeastern US states became the first collection of jurisdictions in the United States to agree to an emissions trading program: Connecticut, Delaware, Maine, New Hampshire, New Jersey, New York, and Vermont. Maryland joined in 2006, Massachusetts and Rhode Island joined in 2007, and New Jersey withdrew at the end of 2011. Total capped emissions were roughly 150 million metric tons in 2011. Known as the Regional Greenhouse Gas Initiative (RGGI, pronounced as "Reggie"), this program only covers large electricity generators, and seeks to reduce emissions from this sector by 10 percent below 2009 levels by 2018. Revenues from allowances—almost all of which are auctioned—go to state governments, which have invested

most revenues in local renewable energy or energy efficiency projects, while roughly 18 percent of revenue goes to state deficit reduction. Offsets for emitters are limited to just 3.3 percent and must come from projects within RGGI states, although no offsets have been used for compliance to date (Regional Greenhouse Gas Initiative 2012b).

After several years of operation, the program has exceeded its initial reduction targets, largely due to fuel switching from coal-fired power to low-priced natural gas. In 2011, overall emissions were 33 percent below the program cap (Regional Greenhouse Gas Initiative 2012a). Allowance prices have not collapsed, thanks to an established floor price in the allowance auctions. However, allowances have gone unsold in the auctions and have generally traded at roughly the floor price during this time.

Voluntary Markets

Voluntary carbon markets refer to a variety of organizations that allow individuals or businesses to purchase offsets from emissions reduction projects located around the world. Since 2002, voluntary markets have grown from \$43 million in revenues to a peak of \$705 million in 2008, and stood at \$572 million as of 2011 (Ecosystem Marketplace and Bloomberg New Energy Finance 2008–2012). Estimated reductions in 2011 were 95 million metric tons. Dozens of organizations offer voluntary carbon offsets, with a variety of procedures and standards for monitoring and verification of carbon reductions.

One important issue for these markets is that their standards for evaluating and monitoring greenhouse gas reduction projects are typically less stringent than, say, the Clean Development Mechanism. On one side, less stringent standards reduce bureaucracy and lead to lower project costs. On the other side, weaker standards could also lead to certification of projects that do not provide their stated benefits (Benessaiah 2012).

New Zealand Emissions Trading System

New Zealand launched an emissions trading program in 2008 that by 2011 covered roughly 32 million metric tons. The program will eventually cover almost all New Zealand emissions, with caps based on New Zealand's 2008–2012 commitment under the Kyoto Protocol. Since New Zealand is a small economy, the program was built around the idea of linking to other markets; this initially includes the Clean Development Mechanism but could be expanded to other national or regional carbon markets (such as the European Union or Australia). This feature has made the program vulnerable to international policy uncertainty and to issues surrounding the CDM. The program covers a relatively small number of large emitters who must reduce emissions, purchase domestic or international offsets, or pay \$25 (New Zealand) per ton of emissions. The program has no price floor and prices have steadily declined through 2012, generally following the movements of CDM prices. Industries facing international competition, horticulture, and fishing receive up to 90 percent free allocation, but the power sector, transportation, and forestry do not receive free allocations (New Zealand Government 2012).

California, Australia, and Others

Two new carbon markets are just in the process of emerging and gaining experience. First, in California, a new cap-and-trade program held its first auction in December 2012 in advance of its 2013 start date (over-the-counter contracts have been traded since at least December 2011). The trading program will initially cover the power sector and some heavy industry, with two-thirds of allowances auctioned. By 2015, it will expand to cover transportation fuels and auction 80 percent of allowances. Emitters may meet up to 8 percent of their obligations through approved domestic offsets and in the future possibly through international forestry offsets. Given California's stature as the world's sixth-largest economy, this is a significant new market with annual capped emissions of roughly 160 million metric tons in 2013 and roughly 400 million metric tons by 2015.

In Australia, after a long and contentious political process, a 2011 law passed that requires an emissions trading program to begin in 2015. In the meantime, major carbon emitters will pay a steadily increasing carbon tax set by the legislation, though many large emitters will receive government support in the form of a large share of free allowances (Australian Government 2012). Much of the government revenues from the tax and subsequent auctions will go towards new spending on energy efficiency, renewables, and technology programs, and at least half of the revenues will go towards increased pension payments, increased tax credits, and decreased income taxes for households. However, the opposition Liberal party has made repealing the carbon price "the top priority" on its agenda, calling into question the policy's viability moving forward (Australia Liberal Party 2012).

Carbon markets also exist at smaller scales, and some large ones are brewing in other jurisdictions. The Canadian province of Quebec has developed a market which will link with California. Recent legislation passed in South Korea and Mexico has laid the groundwork for new national-level programs beginning in 2015. China has established a series of regional pilot programs, while other programs under discussion in India, Japan, Vietnam, and Thailand indicate an interest in cap and trade across much of Asia. Other emissions-trading proposals are currently under discussion or development in Brazil and Chile, among other places (Hood 2010).

Lessons from the Early Carbon Markets

Emissions Fall, But How Much is Unclear

The presence of a consistent and significantly positive price on carbon suggests that these trading programs should be having at least some effect on behavior that reduces emissions levels, but research on the extent of these reductions remains limited.

One way to approach the abatement question is to estimate emissions reductions based on elasticities derived from related policy simulations. A rough analysis of projections from the emissions trading program in the proposed US Waxman-Markey 2009 legislation suggests that for each \$10/ton increase in the price of

US carbon dioxide allowances, emissions from 2012–2015 would fall between 1.5 to 6 percent compared with a scenario with no price on carbon dioxide emissions.² If similar economic dynamics are at play in Europe’s Emissions Trading System, an allowance price of \$16/ton (the Phase I average) would suggest that the program resulted in reductions of 2–9 percent compared with business as usual. Indeed, empirical research on Phase I of Europe’s ETS suggests that during 2005–2007, emissions fell by 2–5 percent compared with business as usual (Ellerman, Convery, and de Perthuis 2010).

A key question for—and sometimes criticism of—current market-based policies concerns the degree to which they encourage long-term investment in new technologies rather than solely short-term fuel-switching and energy conservation. Early research into Europe’s Emissions Trading System suggests that such long-term investments may be limited (Leiter, Paolini, and Winner 2011). However, carbon markets may be still too new to inspire the long-term confidence to make those investments.

Allowance Allocation in the Power Sector Can Involve Important Distributional Effects

Emission allowances can be auctioned, allocated for free, or some combination of the two. There are both distributional as well as efficiency consequences to allowance allocation, and these can be substantial given the sizable economic rents at stake. The power sector is a particularly important area of concern because of its large share of emissions, its universal inclusion in all existing programs, and the complexity of both power markets and the power market regulation influencing the distribution of costs.

In deregulated power markets where fossil-fueled generation tends to be the marginal producer and to set the market price, economists would expect competitive pressure to lead power prices to reflect the price that is placed on carbon content, regardless of any free allocation. Consequently, end users of electricity would ultimately end up paying for compliance costs. In Germany, for example, power generators received carbon allowances for free, and then passed along the opportunity costs of these free allowances to their customers, allowing generators to extract rents roughly comparable to their proportion of freely allocated allowances (Ellerman and Joskow 2008; Sijm, Hers, Lise, and Wetzelaer 2008; Ellerman, Convery, and de Perthuis 2010). This market outcome was completely predictable, though not warmly received by the public (Gow 2006; Harrison 2009).

There are several possible responses to concern over the costs of free allowances being passed along to consumers in the form of higher prices. After providing substantial free allocations early on, the European Commission has more recently limited free allocations of carbon allowances to electricity generators, and it will sharply increase the proportion of allowances sold at auction in its third phase (European Commission 2012c). Other programs have varied in their approach,

² Authors’ analysis of data from Energy Information Administration, “Energy Market and Economic Impacts of H.R. 2454, the American Clean Energy and Security Act of 2009.” Similar ranges can be estimated from other analyses.

with New Zealand giving no free allocations to the power sector and the Regional Greenhouse Gas Initiative giving very few, while Australia will give substantial but temporary free allocations to its coal-heavy power fleet.

When free allocations in the power sector are eliminated, governments take the impact of the emissions trading program on consumer power prices as given and redistribute the rents from auctioning in a more acceptable manner. The opposite approach is to try to limit the higher prices to consumers. For example, cost-of-service regulation could prevent generators from passing through the opportunity costs of carbon permits to consumers even with free allocations to generators. In California's program, free allowances will be provided to the power sector on the condition that they use those allowances to reduce costs for ratepayers. Other proposals to direct free allocations to local power distribution companies or to pursue tradable performance standards, instead of cap and trade, reflect similar efforts to alter the distributional impacts on electricity consumers (for example, Aldy 2011). By limiting the effect on consumer power prices, however, all of these approaches reduce the incentive to conserve electricity.

Part of the motivation for depressing consumer power prices is that carbon pricing, or anything else that raises power prices, disproportionately harms low-income households (Hassett, Mathur, and Metcalf 2009). Rather than limiting the increase in power prices, a number of mechanisms have been proposed to ameliorate the regressiveness of carbon pricing, including lump-sum rebates to households (so-called "cap-and-dividend") and parallel offsetting changes to income or social security taxes (Burtraw, Walls, and Blonz 2010). From an efficiency point of view, these are better compensation mechanisms vis-à-vis depressing power prices and, in the case of tax reform, take advantage of opportunities to lower distortionary taxes.

Significant Competitiveness Effects and Emissions Leakage Have Not Yet Emerged

Another motivation for depressing the impact of carbon pricing on energy prices has been the concern that emission-related activities, particularly energy-intensive industries facing outside competition, will relocate to an unregulated jurisdiction when faced with an emissions trading program that raises production costs. This concern involves an environmental angle—that emission reductions are simply being shifted outside the boundaries of the trading program—referred to as emissions "leakage." It also involves an economic angle—that local industries are being harmed to the advantage of industries abroad, who can be viewed as skirting their environmental responsibilities (Jaffe, Peterson, Portnoy, and Stavins 1995). Facing the practical constraint of a less-than-global response to a global externality, efforts to limit price changes and leakage through various allocation incentives may even be cost-effective (Fischer and Fox 2009). Rather than depress local price increases, programs could also attempt to adjust foreign prices at the border, although this approach raises controversial legal and practical issues (van Asselt and Brewer 2010).

Even without explicit efforts among existing programs to depress carbon-related energy price increases, significant competitiveness impacts and leakage have yet to

emerge. For the early phases of Europe's Emissions Trading System, a (limited) empirical literature indicates that competitive losses appear to have been small. Ellerman, Convery, and de Perthuis (2010) found "no observed impact" on competitiveness in the oil refining, cement, aluminum, or steel sectors during Phase I. Demailly and Quirion (2008) found that Phase I created only a small loss of competitiveness in the iron and steel sectors. Lacombe (2008) found a similar limited impact on the refining sector during Phase I. An analysis of Europe's aluminum sector by Reinaud (2008) found no statistical evidence of negative competitiveness impacts from the program. The only countervailing evidence comes from a survey of firm managers (215 respondents across all affected industries in the European Union) where 55 percent of metals manufacturers and 44 percent of pulp/paper and cement/lime/glass manufacturers stated they have either moved or are considering moving out of Europe's carbon market compliance zone; 14 percent of the remaining firms stated they have moved or are considering such a move (Point Carbon 2011).

These observed competitiveness impacts generally fall below the levels predicted by some earlier analyses (Aldy and Pizer 2008; Ho, Morgenstern, and Shi 2008; Interagency Competitiveness Analysis Team 2009). This may reflect the modest targets for greenhouse gas reduction implemented in the first phase of the European System. It may also reflect the consequences of free allocation to many energy-intensive industrial sectors. Despite the above-noted trend towards auctioning allowances in the power sector, these industrial sectors continue to receive significant free allocations. For a detailed discussion of this issue, see Ellerman, Convery, and de Perthuis (2010, chap. 4).

Limited evidence also suggests that leakage in the Regional Greenhouse Gas Initiative has been small, despite some early concerns and analysis to the contrary. Some research had suggested leakage rates could range from 28 percent with \$3/ton prices to 90 percent with \$7/ton prices (Chen 2009; Wing and Kolodziej 2009). However, low carbon prices resulting from a weak economy and historically low natural gas prices appear to have prevented extensive leakage in RGGI (Kindle, Shawhan, and Swider 2011).

A Variety of Tools Can Be Used to Manage Concerns about Costs and Volatility

Newly started carbon markets face substantial uncertainty over costs and, even though many markets have seen low prices in 2012, program designers still seek to prevent the risk that allowance prices might exceed economically and politically tolerable levels. Research on climate policy instrument choice under uncertainty also suggests that policies exhibiting stable prices and less-certain emissions, as typically associated with a carbon tax, have higher expected net benefits than policies where emissions are fixed and prices fluctuate—as in a rigid cap-and-trade system (Pizer 2002; Newell and Pizer 2003).

Carbon trading programs have typically turned to one or more of the following three types of cost management. First, regulators can impose a price ceiling, allowing emitters to purchase unlimited (or a relatively large volume of) allowances directly from the government at the ceiling price. For example, participants

in the California and Quebec programs will be able to purchase credits from the government for \$40–\$50/ton, essentially capping trading prices (Western Climate Initiative 2012). Australia has established a carbon tax for the first two years of their program, allowing unlimited emissions at \$23 (in Australian dollars) and placing a binding cap on emissions only in 2015 (Australian Government 2012).

Second, regulators can employ price floors to prevent market prices from falling below a certain level. Auction price floors—where allowances are kept out of circulation unless purchasers are willing to pay a minimum price—have been used in the Regional Greenhouse Gas Initiative and in California, and are part of anticipated programs in Australia and Quebec. In California’s November 2012 allowance auction, for example, only 14 percent of the 2015 allowances sold at the minimum price of \$10, leaving 86 percent unsold (California Air Resources Board 2012). Price floors clearly reduce cost uncertainty by limiting low-cost outcomes. But in limiting the possibility of very low prices, these mechanisms can unlock opportunities for negotiation on other features—such as the cap, offset provisions, and/or price ceilings—to reduce the possibility of high costs. As we have seen in the Regional Greenhouse Gas Initiative, price floors can continue to provide an incentive for emissions reductions even if the imposed cap is not binding. Supporting these efforts, theoretical work has showed that price-like modifications within a cap-and-trade program—ceilings and floors on the allowance price or otherwise adjusting the cap to accommodate cost shocks—can help to achieve the same outcomes as a carbon tax, where the cost is certain (Newell, Pizer, and Zhang 2005; Murray, Newell, and Pizer 2009).

A third approach is to allow high carbon market prices to trigger provisions that relax constraints of the program other than the cap itself. If carbon prices reach \$7/ton, for example, the Regional Greenhouse Gas Initiative allows emitters to purchase more carbon offsets to meet their compliance needs than is otherwise allowed. If prices reach \$10/ton, emitters may purchase still more offsets to reach their targets. Unlike explicit expansion or contraction of the emission cap through allowance sales at a fixed price, the exact impact of these mechanisms is less transparent. On the one hand, the capacity of offset markets to expand in response to newly triggered RGGI demand may not be sufficient to ward off higher prices. On the other hand, if offset markets do respond quickly, prices could spike then fall, creating additional volatility.

The Flexibility to Trade Allowances over Time—Banking and Borrowing—Can Smooth Uncertain Cost Shocks with Minimal Environmental Consequence

Emissions of carbon dioxide and most of the other greenhouse gases remain in the atmosphere for decades if not centuries, and the accumulated stock of such emissions is what leads to environmental problems. In other words, the timing of emissions in terms of day, month, or year is not consequential for climate impact. This intuition lies behind the aforementioned preferences for stable prices. Allowing flexibility through banking or borrowing of allowances across time, even without turning to price floors and ceilings, can smooth out prices and costs, increasing

cost-effectiveness without additional harm to the climate (Fell, MacKenzie, and Pizer 2012).

In this way, banking carbon allowances can be a partial response to concerns about uncertain costs (although the problem remains if costs are headed permanently higher or lower). Without trading between periods, cost shocks have to be absorbed immediately. Europe's experience during the first phase of its Emissions Trading System, which did not allow banking, provides a prime example. Facing unexpectedly low compliance costs, prices for carbon allowances collapsed. Unlimited banking is now allowed in all carbon trading programs, though few allow borrowing. An emerging question is how much banking an emissions trading system can (and perhaps should) support. For example, recent estimates suggest market participants in the European Union system are banking nearly 2.5 billion allowances, roughly 119 percent of Phase II's annual cap, for carryover into Phase III (Neuhoff, Schopp, Boyd, Stelmakh, and Vasa 2012). For reference, the US sulfur dioxide cap-and-trade program saw banking levels of over 6 million tons in 1998, or roughly the volume of the annual cap (Stavins 1998).

Policies that allow banking of carbon allowances do face some challenges. Banking links expectations over time, so prices today depend on expected prices tomorrow. Depending on the government's level of commitment to the policy and the public's perception of that commitment, this can be a good or bad thing. (We return to the issue of future policy adjustments below.) Recent low prices in Europe, for example, have been linked to questions about whether an aggressive renewables policy will depress carbon prices in the future (Grubb 2012).

Another issue raised by the potential movement of allowances across time is the trading ratio that should be applied to banked or borrowed allowances, and how this rate should be applied. Theory suggests that the optimal trading ratio between periods is equal to one plus the discount rate, minus the desired rate of change in permit prices (Leiby and Rubin 2001). In addition to this formula, a discount rate is required, which raises a distinct set of analytical challenges, for both the estimation of damages and the rate at which the carbon price should rise (Interagency Working Group on Social Cost of Carbon 2009; Aldy et al. 2010; National Research Council 2010). In practice, banking has faced a trading ratio of unity, sometimes coupled with very limited amounts of borrowing. Where allowed, large-scale borrowing has typically faced a trading ratio equivalent to one plus a discount rate (in Kyoto, this was a trading ratio of 1.3 over five years; under the Waxman-Markey legislation, the discount rate would have been 8 percent per year).

Offsets Can Provide Low-Cost Mitigation Options, but Raise Complex Issues

Offsets allow mitigation activities outside a cap-and-trade system to count against the cap, expanding the scope of potential responses and thereby lowering costs. Developing-country emissions offsets, in particular, offer a very large potential pool of inexpensive compliance opportunities for industrialized nations, relative to reducing greenhouse gas emissions within their own borders (Weyant and Hill 1999). Domestic or local offsets can also offer cost savings while keeping investments and cash flow

at home, but represent a smaller universe of activities compared to international offsets. Although specific provisions and restrictions vary, all programs to date employ offsets in some capacity. However, difficulties arise in assuring that offsets provide actual reduction in emissions and that the subsidy effect from offset crediting is not creating perverse outcomes. In addition, as financial flows to offset projects grow, attention can shift to questions of distribution as well as efficiency.

For offsets to reduce emissions, credits can only be given to projects (and for measurable reductions) that would not have occurred without the offset credit program. At the same time, rigorous screening creates transaction costs that eat into potential cost savings. In practice, offset programs must strike a balance, and a variety of approaches have emerged (Hall 2007). As the world's largest offset program, the Clean Development Mechanism has pioneered many of these approaches, and considerable research indicates that it has resulted in real emission reductions taken as a whole. However, it is easy to find subcategories of projects where researchers question whether the reductions were real (Lambert 2011; Zhang and Wang 2011).

The most problematic example from the Clean Development Mechanism involves HFC-23, a compound produced primarily as a by-product in the production of refrigerants in developing countries. As a by-product, HFC-23 is typically vented to the atmosphere where it has roughly 10,000 times the global warming potential (ton-for-ton) compared to carbon dioxide (United Nations Framework Convention on Climate Change 2012a). Because of its high global warming potential, projects that destroy the HFC-23 by-product receive large amounts of credits—enough to make it profitable to increase operations that emit HFC-23 in the present, just to destroy more HFC-23 in the future. Lambert (2011) found evidence of such behavior in the first few years of the program, leading the European Commission (and later Australia and New Zealand) to disallow such credits and encouraging the CDM itself to revise its guidelines concerning HFC-23 and similar gases.

Forestry offset projects have also been a particularly thorny issue, as carbon stored in stands of trees is—by its nature—difficult to guarantee and deforestation avoided in one area can easily crop up in another. Yet the allure of preserving forests while sequestering carbon has attracted tremendous interest. Currently, California allows certain forestry offsets, as do many voluntary programs. The European system does not allow forestry or land-use change projects (Kim et al. 2008). New Zealand has included domestic forestry under its national cap. The complexity in dealing with forestry has led to a variety of proposals that continue to be debated (Murray, Galik, Mitchell, and Cottle 2012).

As the use of international offsets grows, a variety of distributional questions can arise due to the transfer of resources from higher-income nations to developing nations. Through 2011, by far the largest share of projects and credits were going to China and India. In fact, between 2006 and 2011, over half of each year's Clean Development Mechanism credits went to projects in China—topping out at 75 percent in 2007 (data from CDM/JI Pipeline <http://www.cdmpipeline.org>). Since China is the world's largest carbon emitter, it is not surprising that a large share of carbon reduction projects would occur there. However, those nations or political stakeholders that

believe China should commit to a more stringent emissions reduction plan, or see China as a competitor, may object to the transfers enabled by the CDM (International Energy Agency 2012). More broadly, whether the CDM projects are meeting broader development objectives, such as economic growth or technology transfer, remains uncertain (Dechezlepretre, Glachant, and Menier 2008; Popp 2011).

One solution to the distributional issue is to focus international offsets on poorer countries; another is to emphasize regional or local offset programs. The Regional Greenhouse Gas Initiative, and California, Quebec, and Australia each encourage and accept for compliance regional or local offsets, and in the case of Australia, a domestic offset program that encourages emissions reductions on farms is a central tenet of the overall program (Australian Government 2012). Even if local offsets are more costly, they are sometimes favored by local authorities. For example, regional programs in North America have thus far given preference to offsets from regional or domestic emissions reduction projects—although these programs also allow offsets to make up just a small share of compliance.

It is impossible to conclude a discussion of offsets without at least noting the collapse of the Clean Development Mechanism market at the end of 2012. After remaining around €10–15 per metric ton for most of 2009, 2010, and the first half of 2011, CDM prices fell steadily to less than €1 in November and December 2012. This has been ascribed to increased limitations on the use of CDM credits in the European Union, uncertainty about future demand, and increasingly robust supply—issues that will need to be sorted out for investors to continue to have confidence in offset markets.

Market Monitoring and Oversight Must Be an Integral Feature of Cap-and-Trade Programs

After the 2008 financial crisis, virtually all financial markets came under new scrutiny. Carbon markets were no exception, and new proposals for trading programs in the United States came with calls for strong oversight. In fact, the 2010 Dodd–Frank financial reform and consumer protection bill created an interagency working group to conduct a study on maintaining and increasing transparency for carbon markets (Interagency Working Group for the Study on Oversight of Carbon Markets 2011). Similarly, an EU directive adopted in 2011 will significantly expand oversight of carbon markets (European Commission 2012b). Primary goals for market oversight include facilitating price discovery, ensuring transparency and access to information, and preventing manipulation or abuse in the marketplace. However, European governments have come under criticism for not releasing timely and detailed data on individual allowance trades and holdings (de Perthuis 2011).

The European Emissions Trading System has faced three high-profile market controversies, two of which were not specific to emissions trading markets. One of these two cases involved traders manipulating value-added tax laws in different countries to defraud governments of over €1 billion from 2008–2009, while the second involved cyber-attacks which likely stole over €50 million worth of allowances on spot exchanges in 2011 (de Perthuis 2011; Frunza, Guegan, and Lassoudiere 2011). The

one major controversy unique to emission markets occurred when Clean Development Mechanism credits previously collected by the Hungarian government for compliance re-entered the market. It appears that the Hungarian government simply swapped the CDM credits for another type of carbon asset under the Kyoto Protocol that it needed to sell. While the swap was legal under the Kyoto Protocol, it was surprising to many participants in the European Emissions Trading System and created the appearance of possible credit “recycling” that would have negated relevant carbon reductions and diminished the integrity of the trading system (de Perthuis 2011). The European Commission has since revised its rules to address each of these concerns.

As for the Regional Greenhouse Gas Initiative, the program’s independent market monitor has found no major irregularities since trading began in 2008 (Potomac Economics 2009, 2010, 2011). Market and auction data is released by RGGI regularly, and allowance holdings are traceable online through the program’s CO₂ Allowance Tracking System (see <http://www.rggi-coats.org> for details).

The Future of Carbon Markets: New Issues

A more general lesson from the past decade is that climate policy and carbon markets are not static concepts, but are instead constantly evolving. The vision of a single, top-down global trading system has morphed into the reality of various national and subnational trading programs. These programs are themselves evolving over time as are views about the relative role of carbon markets vis-à-vis other policy responses. Against this backdrop, carbon markets face a variety of emerging issues.

Linking Carbon Markets

Front and center in the discussion of current carbon markets is how, whether, and when different markets can be “linked” so that regulated entities in one jurisdiction can use allowances or credits from another jurisdiction for compliance (Jaffe, Ranson, and Stavins 2009). It might seem as if linking two carbon markets must always be a universally positive step by adding additional flexibility for trading; but when carbon markets have certain characteristics, this conclusion is incorrect. For example, Fischer (2003) shows that linking a system that is indexed to output with an ordinary capped system almost always increases emissions. Researchers have begun to think about exactly which features have to be aligned to avoid such issues, and which do not (Mace et al. 2008).

In practice, linkages may be one-way or two-way (Mehling and Haites 2011). In a one-way linkage, credits in one system can be used for compliance in another, but not vice-versa. In a two-way linkage, both systems mutually allow the other’s credits to be used for compliance.³ It is also useful to think about even one-way linkages in

³ Linkages can also be indirect: If system A links to B and B links to C, A will have an indirect linkage with C. For example, A’s credits can be used for compliance in B, freeing up B’s credits to move into C. The net result would be credits leaving A and entering C.

terms of buy-linkages and sell-linkages: that is, a buy-linkage represents the decision by one trading system to accept for compliance allowances or credits created and offered for sale by another system, while a sell-linkage represents a decision by one jurisdiction to allow or encourage other jurisdictions to use its allowances or credits for compliance. A complete two-way linkage really involves two distinct decisions about buying and selling by each of two jurisdictions.

Linkages among trading systems have proceeded relatively slowly so far, for three main reasons. First, buyers tend to be concerned about environmental integrity and so will be careful in accepting that purchased allowances are valid for compliance in their system (Mace et al. 2008). Second, the necessary harmonization of certain design features also means that one or the other system is giving up some sovereign control. The result often depends on who has more power in the linking negotiation, which is frequently a function of the relative market size. Currently, for example, the European Union set the terms for Norway, Iceland, and Lichtenstein to enter the Emissions Trading System. In a different model, emitters under Australia's program will be able to purchase European allowances overseen by the European Commission in 2015, while European emitters will be allowed to purchase allowances from Australia in 2018 (Reklev 2012). In North America, Quebec's program embraces many aspects of the California design and will likely soon link to that much larger market (Carroll 2012).

Third, distributional concerns tend to arise, particularly in the selling system. For the buying system, linking lowers allowance prices with the same environmental outcome—something many programs desire. The main downside is faced by investors holding allowances without any corresponding obligations, or the government in the case of auctions. But for the selling system, linking raises allowance prices for carbon allowances, increasing costs for those with compliance obligations as well as their downstream consumers. For this reason, Australia initially planned to restrict international sales of its allowances, despite the net gains from trade (Jotzo and Betz 2011).

New Information and Program Revision

One of the defining characteristics of climate change is uncertainty about both mitigation costs and benefits as economic conditions, technologies for carbon abatement, and scientific knowledge advance. Occasional revisions to carbon market policies are essential to long-term efficiency (Murray, Newell, and Pizer 2009). While markets and affected stakeholders may crave certainty, governments cannot guarantee certainty where it does not fundamentally exist. Carbon market policies are certain to be revised and even overhauled as time passes.

Carbon market policy revisions have the potential to create financial gains and losses in the carbon market. At any point in time, carbon market participants have both carbon assets in the form of allowances, and liabilities in the form of expected emissions. As expected carbon prices change, so do the balance sheets of these economic actors. While the same would be true for changes in carbon taxes, the existence of banking provisions—which link carbon prices over time through

the potential for arbitrage—imply that any change in future price expectations should also affect current prices. Like expected shifts in conventional regulation, expected changes in carbon market policies also affect incentives for investing in new, emission-related physical capital and technology, as well as the value of the current capital stock.

For example, as Europe's Emissions Trading System enters its third phase in 2013, it is reportedly considering a delay in auctioning a large share of allowances (roughly 900 million from 2013–2015); a delay would likely drive up prices until the auction date becomes certain (Allan 2012; Szabo 2012). Most European governments expected to gain from the plan, as higher prices offset lower auction volumes; Poland's government has opposed the delay, however, because its auction volume is small and it expects to lose revenue. The Regional Greenhouse Gas Initiative saw a decrease in the size of its market when New Jersey announced in May 2011 that it would withdraw at the end of the year (Christie 2011). However, prices were unaffected, perhaps in part because they were already trading at the established price floor. In New Zealand, rules were revised to allow only one allowance to be used for two tons of emissions (rather than one ton) during a transition phase (Fallow 2009). This did not substantially impact New Zealand allowances prices, which are closely tied to Clean Development Mechanism prices determined internationally, but halves the emission reduction incentive for New Zealand firms.

If the holders of allowances are largely the same agents who face compliance obligations, the net effect of price changes on firms' balance sheets could be relatively small, as the market value of allowances will fluctuate along with the cost of their future compliance obligation. However, the specifics of how allowances are valued on balance sheets can create problems even for these businesses. For allowance holders that have no compliance obligations, and for those with obligations but no allowances, the financial consequences of large price changes could be substantial.

Policy revisions cannot be avoided, but governments should strive to make them transparent and orderly. Regulatory agencies, courts, legislatures, and central banks all face the need to pursue market-sensitive decisions in a way that allows all market participants equal access to information as well as advance notice of the sequence and timing of the decision process. For example, one legislative proposal for a US carbon market (Low Carbon Economy Act of 2007, S. 1766, 110th Congress) would have implemented a specific schedule for periodic five-year reviews and revisions, with presidential submission of recommendations shortly after the compliance year ends and then expedited Congressional action within six months.

Another option might be to put these decisions into the hands of an oversight entity, similar to a central bank (Pizer and Tatsutani 2008); Newell, Pizer, and Zhang 2005). Such an entity would be responsible for periodic reviews and changes to the emission limit or other rules, and would have the flexibility to do so outside the explicitly political sphere. However, climate change is an issue with a continuing divergence of views about the appropriate level of response, even among experts, and the independence of an oversight entity cannot solve that problem.

Alternative Policies and Comparability

In addition to finding ourselves in a world of multiple emission trading regimes with varying rules, many jurisdictions are pursuing alternative policy approaches such as a carbon tax or more traditional regulation. For example, policy-related emission reductions in the United States over the past few years have arisen from tighter regulations on automobile fuel economy and tailpipe greenhouse gas emissions, renewable electricity capacity additions associated with federal and state subsidies and mandates, and new power plant emission regulations from the US Environmental Protection Agency. The European system only covers roughly half of European emissions, with traditional regulation used elsewhere (for example, with automobiles). Several European nations, such as Great Britain, Ireland, the Netherlands, and Norway, also apply carbon taxes to certain fuel types. Australia is temporarily using a carbon tax in advance of emissions trading.

This diversity of policy approaches was not altogether unexpected. Under the Kyoto Protocol, there is no requirement to use a carbon market as the sole tool to implement a domestic emissions reduction program. When the United States seemed closest to establishing its own cap-and-trade program in 2009 and sought to assuage domestic concerns about competitiveness, the proposed legislation asked other countries to have a “nationally enforceable and economy-wide greenhouse gas emissions reduction commitment for that country that is at least as stringent as that of the United States” without specifying emissions trading (see H.R. 2454, §767(c)(1), 111th Congress).

This diversity of approaches raises the need to measure the “comparability” of policies. Among jurisdictions with carbon markets, comparability is necessary for jurisdictions to consider linking. More generally, comparability among jurisdictions with and without carbon markets is necessary for countries to justify continued domestic action on a global problem and, more specifically, to avoid escalating concerns over competitiveness and emission leakage that could threaten the sustainability of policy actions. Most discussions look at emission reduction efforts in one of six ways: 1) emission reductions versus some year in the past; 2) reductions versus what would happen with a business-as-usual baseline; 3) reductions in emissions per unit of output (gross domestic product, energy use, power generation); 4) reductions in emissions per capita; 5) the realized carbon price; or 6) energy prices or price effects. There is no agreement on which metric is best, many raise practical issues like conversion of carbon prices among currencies or calculation of business-as-usual forecasts, and different metrics yield dramatically different messages. This question of comparability is compounded when evaluating actual implementation of policies and their outcomes, as opposed to pledges.

International Negotiations

Earlier, Kyoto-style negotiations focused on a sequence of top-down, larger-to-smaller emission trading issues—national emission caps, trading rules, and then further details, such as the Clean Development Mechanism. However, the new

negotiations in the aftermath of the Durban conference in late 2011 will necessarily focus on the tools for a bottom-up approach. On the one hand, a new agreement will need to support concerns over comparability and transparency of effort. Those countries already engaged in or pursuing carbon markets will want assurances that other jurisdictions will do their fair share.

A new international agreement also needs to focus on ways to provide institutional support for markets themselves. For example, some developing countries might benefit from “model rules” for establishing a domestic trading program that would presumptively link to developed country programs already utilizing the Clean Development Mechanism. While rules for carbon markets and other abatement programs can and may emerge organically without an anchor in international agreements, creating model rules could be valuable, particularly for the many countries that will be too small to pursue an entirely customized approach. There are also questions about the future of the CDM itself. Decisions in December 2012 will limit future access to the CDM to countries participating in the next phase (2013–2020) of the Kyoto Protocol. This approach steers the CDM away from a role in a decentralized global carbon market by limiting its relevance to the subset of Kyoto participants. To achieve efficiency, future negotiations should be creating opportunities for linkages, not blocking them.

Conclusion

Fifteen years after the signing of the Kyoto Protocol and the creation of the first major platform for carbon markets, the prospect for a unified global carbon trading system in the foreseeable future is essentially finished. However, carbon markets are a reality and the design of carbon markets is benefiting from actual experience. Experience with windfall profits from free allowance allocation has led to an increased use of auctions. Jurisdictions are learning to handle market-sensitive information in a more transparent and orderly manner, although progress remains to be made. Efforts to moderate both high and low prices are providing lessons on what works. Perhaps most importantly, we are seeing that carbon allowance trading can support emission reductions and send market signals for future investment. The challenge now is to figure out how carbon markets can work in a much more complex—but clearly more realistic—world.

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