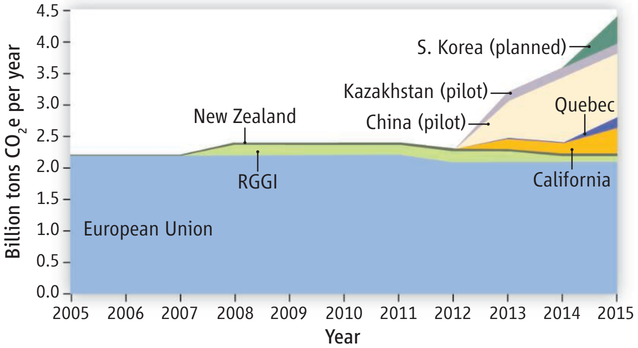
ENVIRONMENTAL ECONOMICS

Carbon Market Lessons and Global Policy Outlook

Ongoing work on linking markets and mixing policies builds on successes and failures in pricing and trading carbon.

Richard G. Newell,[1,2,3]* William A. Pizer,[1,2,3,4] Daniel Raimi[1]

Prices in the European Union's (EU) Emissions Trading System (EU-ETS) spent 2013 at historic lows. Elected officials have promised to repeal the Australian carbon market. Yet five new regional carbon markets recently began in China, which nearly doubled the volume of emissions covered by trading programs. This follows California's successful launch of its cap-and-trade program in 2013 and its 2014 link to Quebec's market. Are carbon markets seriously challenged or succeeding and on the rise?



Estimated annual emissions subject to existing, pilot, and planned carbon markets. CO_2e reflects inclusion of non-CO_2 greenhouse gases converted to an equivalent amount of CO_2 based on radiative forcing. See (*2*) for details.

Sixteen years after the Kyoto Protocol was signed and the idea of emissions trading emerged as a dominant policy paradigm, we have learned much about what makes carbon markets work—and what does not. New questions are emerging for researchers and policy-makers, including how carbon markets fit into a complex global framework.

Think Global, Act Local?

A truly global trading program is as yet unlikely, if not impossible. Because a unit of carbon dioxide (CO_2) emitted anywhere has a uniform impact on global climate, a single global market would be economically desirable, equalizing incentives to reduce emissions everywhere. In practice, we see a multiplicity of multinational, national, and subnational markets—including the European Union, California, Quebec, the Regional Greenhouse Gas Initiative (RGGI) in the U.S. northeast, and New Zealand, as well as pilot programs in Kazakhstan and China, and programs under development in South Korea and Mexico (see the graph).

Might these programs merge into an integrated global market? This is one of the most important questions facing researchers and policy-makers. Whether, how, and when should markets link together so that regulated entities in one region can use allowances or credits from another, thereby equalizing prices (*1*)? The answers are not easy, as economic arguments in favor of linking must be weighed alongside concerns about environmental integrity, harmonizing politically sensitive program features, and financial flows arising from international carbon trade.

A positive price on carbon in every existing program suggests that markets are reducing emissions below what they would otherwise be. If emissions were not being constrained by the carbon market, then emission allowance supply would outstrip demand in aggregate, and the price would move toward zero. Research on the extent of climate change mitigation, however, remains limited (in part, because complex modeling is required to estimate the "no carbon market" counterfactual). A simple calculation suggests a global, emission-weighted average carbon market price of \$6.50 per ton in 2013 (*2*). On the basis of previous modeling studies, this price suggests a modest 1.5 to 3.5% decline in covered emissions (*3*), an annual reduction of about 40 to 90 million tons of CO_2 attributable to existing carbon markets (*2*).

Greater emission reductions and carbon prices well above these levels are necessary to meet the most commonly identified environmental goals (*4*, *5*). Higher prices are also justified by economic analysis. The most recent U.S. government estimate of the global damages from climate change produced a central value of about \$35 per ton of CO_2 (*6*). This "social cost of carbon" synthesizes scientists' best estimates of climate change impacts—and economist's valuation of those impacts—from one ton of CO_2. When market prices are below the social cost of carbon, it suggests that higher prices are warranted to fully charge sources for the impact of their emissions.

Part of the story behind low carbon prices is that emissions trading is increasingly only one of several overlapping programs encouraging mitigation. For example, major incentive programs for renewable energy and energy efficiency exist in California and the European Union. These other policies produce targeted emission reductions, leaving the broader carbon market to achieve the (now lesser) remaining reductions. This tends to lower the carbon price but increase overall mitigation costs (*4*, *7*). This raises a question: How do policies work together to achieve goals that extend beyond reducing emissions at the least cost?

Rents, Leakage, Uncertainty

Emission allowances can be auctioned by the government, given to firms (free), or some combination. In the early phases of the EU program, some power producers received carbon allowances at no cost in an attempt to limit consumer price increases. However, depending on the structure of power markets, utilities were able to pass on the market price of the allowances to their customers (*8*, *9*). This was predictable to economists, although not warmly received by the public, who saw companies receiving "windfall profits" from higher electricity prices. These "rents," net profits received on allowances, are ultimately paid by someone, in this case, consumers. As a result, most carbon markets now limit or eliminate free allocation of allowances to the power sector and instead return revenues from allowance sales to public coffers.

Some programs have attenuated these power price increases, reducing both rents and associated end-user impacts. This can be accomplished in a variety of ways, including renewable energy and efficiency policies that take the burden off the carbon price (*10*). Lower power prices have the

[1]Duke University, Durham, NC 27708, USA. [2]National Bureau of Economic Research, Cambridge, MA 02138, USA. [3]Resources for the Future, Washington, DC 20036, USA. [4]Center for Global Development, Washington, DC 20036, USA.

*Corresponding author: richard.newell@duke.edu

downside of reducing conservation incentives, and overall economic efficiency in turn, however.

Many stakeholders have expressed concerns about economic competitiveness, e.g., that energy-intensive industries facing outside competition will relocate to places without a carbon price. This concern has an environmental angle, emissions "leakage": that emission reductions may simply be shifted outside carbon market boundaries. Evidence seems to indicate that competitiveness impacts and leakage have thus far been small (*11*). Carbon prices have generally been modest. In many programs, heavy industries have received free allowances to compensate for increased production costs. The extent of competitiveness and leakage impacts, as well as pressure to address them, will depend on the future size and persistence of carbon price differences across political boundaries.

Carbon markets face substantial uncertainty over prices. Although market prices are relatively modest, program designers seek to prevent allowance prices from exceeding economically and politically tolerable levels. Others have been concerned about unexpectedly low prices undermining mitigation investments, technology development, and long-term environmental outcomes.

Allowance banking is an important tool to avoid short-term supply-demand imbalances and associated price movements, such as occurred because of allowance oversupply at the end of 2007 in the EU-ETS. Allowances issued in 2007 could not be banked for use in 2008, and their price fell to zero even as 2008 allowances traded at more than €25. All carbon markets now allow banking.

Price floors have also been used successfully in the RGGI and California programs to avoid lower-than-desired prices. Both programs employ minimum allowance auction prices to withhold allowances if the market is unwilling to pay the minimum auction price.

Both programs also have limited mechanisms to address high prices. Each maintains a fixed allowance reserve that can only be tapped if buyers are willing to pay an established ceiling price. An open question is how large a reserve is necessary, but there is no reason to believe that price ceilings—with a large enough reserve—would be any less effective for avoiding high prices as floors have been for avoiding low ones (*12*).

Linking, Mixing, Revising Policies

We have alluded to two new challenges confronting domestic policy-makers: linking programs and mixing multiple policies. Each also relates to larger international issues.

Beyond bilateral links, we might ask what can or should be done to facilitate linking multilaterally? The biggest linking story so far was not between two trading programs, but between the EU-ETS and the Clean Development Mechanism (CDM), the United Nations (UN)–sanctioned offset program in developing countries. Over a billion tons of CDM credits have been purchased for compliance in the EU-ETS. Offset projects reduce emissions or absorb carbon and are undertaken by parties not required to obtain permits from the carbon market (*13*). When linked to a trading system, offset credits can be used for carbon market compliance.

There are a variety of challenges faced by offset programs, and the market for CDM credits has essentially collapsed due to a supply-demand imbalance (*11*). However, two strengths of the CDM are that it (i) was sanctioned by the UN Framework Convention on Climate Change and (ii) focuses on developing countries where financial flows arguably raise fewer issues. For example, in the California-Quebec link, Quebecois may question if they should collectively send money to California to pay for emission reductions. Such concerns might be more muted if funds were flowing to poorer countries.

This suggests there is value in approaches that simultaneously facilitate carbon markets in developing countries and links to existing programs in developed countries. For example, this might occur through negotiation of "model rules" for domestic trading programs.

The mixing of multiple carbon policies within countries also raises international issues, including how countries can compare one another's policy portfolios (*14*). For jurisdictions with carbon markets, comparability is a prerequisite to any potential linkage. The ability to compare emissions reduction efforts is also necessary to justify continued domestic action because of concerns over competitiveness, emission leakage, and the imperative that global reductions ultimately require effort from all major emitters.

Climate policy and carbon markets are constantly evolving. For example, development of shale gas in the United States and subsequent expansion of natural gas generation was one of the drivers behind the RGGI states' decision to propose a 45% reduction of their cap level (*15*). Improved representation of abrupt climate change and sea-level rise were among the climate science updates that led to an upward revision of the U.S. government's social cost of carbon by nearly 40% (*6*). Revisions to carbon market policies are essential to long-term efficiency (*12*). Although markets and stakeholders crave certainty, governments cannot guarantee it.

Although policy revisions cannot be avoided, there is value to governments striving to make them transparent and orderly. Regulatory agencies, courts, legislatures, and central banks need to make market-sensitive decisions while allowing market participants equal access to information. With orderly and predictable policy changes, it is possible for markets to incorporate scientific and technological developments into the carbon price before the policy changes occur (*12*).

Carbon markets are now a key part of an emerging, complex, global policy framework that mixes trading programs and other policies at the subnational, national, and multinational level. Fresh research and policy initiatives are grappling with new issues: linking programs (*16*), the consequences and comparability of mixed policies (*17*, *18*), and managing market evolution as policies inevitably change (*19*). The future of carbon markets will depend, in part, on how well such efforts address these and other challenges.

References

1. J. Jaffe *et al.*, *Ecol. Law Q.* **36**, 789 (2009).
2. Materials and methods are available as supplementary material on *Science* Online.
3. A. A. Fawcett *et al.*, *Energy Econ.* **31** (Suppl. 2), S198 (2009).
4. J. E. Aldy *et al.*, *J. Econ. Lit.* **48**, 903 (2010).
5. N. Bauer *et al.*, *Clim. Change* 10.1007/s10584-013-0901-6 (2013).
6. Interagency Working Group on Social Cost of Carbon, "Technical update of the social cost of carbon for regulatory impact analysis under Executive Order 12866" (IWG, Washington, DC, 2013).
7. R. G. Newell, *Oxf. Rev. Econ. Policy* **26**, 253 (2010).
8. A. Ellerman, F. J. Convery, C. de Perthius, *Pricing Carbon* (Cambridge Univ. Press, Cambridge, 2010).
9. J. P. M. Sijm *et al.* "The impact of the EU ETS on electricity prices" (European Commission, Brussels, 2008).
10. D. Burtraw *et al.*, in *U.S. Energy Tax Policy*, G. E. Metcalf, Ed. (Cambridge Univ. Press, Cambridge, 2010).
11. R. G. Newell *et al.*, *J. Econ. Perspect.* **27**, 123 (2013).
12. B. C. Murray, R. G. Newell, W. A. Pizer, *Rev. Environ. Econ. Policy* **3**, 84 (2009).
13. A. van Benthem, S. Kerr, *J. Public Econ.* **107**, 31 (2013).
14. J. E. Aldy, in *Handbook on Energy and Climate Change*, R. Fouquet, Ed. (Elgar, Northampton, MA, 2013), chap. 15.
15. RGGI, "RGGI states propose lowering regional CO_2 emissions cap 45%: Implementing a more flexible cost-control mechanism" (RGGI, New York, 2013).
16. M. Ranson, R. Stavins, "Linkage of greenhouse gas emissions trading systems: Learning from experience" (Working paper 19824, National Bureau of Economic Research, Cambridge, MA, 2014).
17. J. E. Aldy, W. A. Pizer, "Comparability of effort in international climate policy architecture" (Discussion paper 2014-62, Harvard Project on Climate Agreements, Cambridge, MA, 2014).
18. C. Fischer, R. G. Newell, L. Preonas, "Environmental and Technology Policy Options in the Electricity Sector," (Resources for the Future, Washington, DC, 2013).
19. Consultation on structural options to strengthen the EU Emissions Trading System; http://ec.europa.eu/clima/consultations/articles/0017_en.htm.

Supplementary Materials
www.sciencemag.org/content/343/6177/1316/suppl/DC1

10.1126/science.1246907