LESSONS LEARNED FROM SUB-NATIONAL EMISSIONS TRADING SYSTEMS

HARVARD PROJECT ON CLIMATE AGREEMENTS

Supported by Energy Foundation China

In Collaboration with the Research Center for Climate Change, Guangdong University of Technology

Robert N. Stavins
Harvard Kennedy School

June 2021

Lessons Learned from Sub-National Emissions Trading Systems

Harvard Project on Climate Agreements

Supported by Energy Foundation China

In Collaboration with the Research Center for Climate Change, Guangdong University of Technology

Robert N. Stavins
Harvard Kennedy School

June 2021

ACKNOWLEDGEMENTS

This paper was written with the support of Energy Foundation China, as part of a larger project exploring Guangdong Province's greenhouse-gas emissions trading system. The Harvard Project is collaborating closely with the Research Center for Climate Change, Guangdong University of Technology, directed by Professor Zeng Xuelan, in this initiative. The Harvard Project receives support for other initiatives from the Harvard Global Institute, the Enel Foundation, Harvard University Climate Change Solutions Fund, the Belfer Center for Science and International Affairs at Harvard Kennedy School, and the Harvard University Center for the Environment.

THE HARVARD PROJECT ON CLIMATE AGREEMENTS

The Harvard Project on Climate Agreements is a Harvard-University-wide initiative established in 2007 to identify and advance scientifically sound, economically sensible, and politically pragmatic public policy options for addressing global climate change. Drawing upon leading thinkers from around the world, the Harvard Project conducts research on policy architecture, key design elements, and institutional dimensions of international and domestic climate-change policy. The Harvard Project is directed by Robert N. Stavins, A.J. Meyer Professor of Energy and Economic Development, Harvard Kennedy School. For more information, see the Harvard Project's website: www.hks.harvard.edu/hpca.

RESEARCH CENTER FOR CLIMATE CHANGE, GUANGDONG UNIVERSITY OF TECHNOLOGY

The Research Center for Climate Change, Guangdong University of Technology (GDUT-RCCC) promotes low-carbon and green development and provides technical consultancy and research support on climate change. With extensive background in environment, mechanics, statistics, transportation, and economics, the GDUT-RCCC team includes approximately 30 professionals in three institutes, specializing in low-carbon strategy and policy, carbon markets, and low-carbon technologies, respectively. Researchers are currently studying, among other topics, allowance allocation and the MRV system of the Chinese national and the Guangdong provincial carbon market; a low-carbon city development index system; and carbon-emission-peaking theory. GDUT-RCCC's clients include agencies of the Chinese central government and of provincial and municipal governments — and some international governmental bodies and non-governmental organizations.

CITATION INFORMATION

Stavins, Robert N. "Lessons Learned from Sub-National Emissions Trading Systems." Cambridge, Mass.: Harvard Project on Climate Agreements, June 2021.

LESSONS LEARNED FROM SUB-NATIONAL EMISSIONS TRADING SYSTEMS

Robert N. Stavins
Harvard Kennedy School
Cambridge, Massachusetts

ABSTRACT

Given the global commons nature of the climate change problem, international cooperation is essential, and the highest levels of effective governance — typically countries — should be involved as the key jurisdictions to implement effective GHG mitigation policies. However, if national government action is inadequate or if market failures prevent national policies from being effective, then there are potential roles for sub-national climate policies. Theory and experience of nesting sub-national climate policies within a broader, national climate policy indicate that the interactions between the two levels of governance can be problematic, benign, or positive, depending upon the nature, design, and stringency of the national and the sub-national policies. Of particular concern are situations where the national policies are based on averaging of quantities of emissions, such as with cap-and-trade systems. When the national system is a tradable performance standard, as with China's national system planned for launch in 2021, the consequences are similar to those with cap-and-trade, but more complex.

ACKNOWLEDGEMENTS

This paper was prepared with the support of Energy Foundation China, as part of a project exploring the status of — and prospects for — Guangdong Province's greenhouse-gas emissions trading system. Much of the project is conducted jointly with the Research Center for Climate Change, Guangdong University of Technology, directed by Professor Zeng Xuelan. The author thanks the Foundation and the Center, Huang Xiaodan for her translation into Chinese, Hengrui Liu and Raymond Song for additional assistance with translation, and Bryan Galcik for layout and design of the publication. Finally, the author gratefully acknowledges Professor Lawrence Goulder of Stanford University. This paper is based in part on joint research previously conducted with Professor Goulder.

LESSONS LEARNED FROM SUB-NATIONAL EMISSIONS TRADING SYSTEMS

Robert N. Stavins[1]

1. INTRODUCTION

Greenhouse gases (GHGs), including carbon dioxide (CO_2), mix in the atmosphere, and so the location of emissions has no effect on impacts. In economic terms, climate change is a global commons problem. Any jurisdiction taking action incurs the costs of its actions, but the climate benefits of its actions are distributed globally. Therefore, for virtually any jurisdiction, the climate benefits it reaps from its actions will be less than the costs it incurs, despite the fact that the global benefits may be greater — possibly much greater — than the global costs. This relationship is inevitably more severe the smaller the jurisdiction, all else being equal, and explains why international, if not global, cooperation is essential, and why the highest levels of effective governance — typically countries — must be involved as the key jurisdictions for effective mitigation policy implementation.

However, there are several reasons why policy action at lower levels of governance — that is, sub-national governments — can be appropriate, and even necessary. First, if there is a lack of involvement by a particular national government, then actions by sub-national jurisdictions are a second-best approach. Second, if there is national government action but it is judged to be insufficient in terms of stringency or policy design, then there is a potential role for sub-national government to be involved as well.

Third, other market failures — beyond the core externality association with GHGs and climate change — may render a national policy ineffective in some realms, hence calling for other policies, possibly at the sub-national level, to address those additional market failures. For example, in the presence of a national carbon-pricing policy (whether carbon tax or emissions trading), the carbon price signal may be obscured by specific market failures. One well-known example of such an additional market failure is the principal-agent problem in renter-occupied properties.[2]

Finally, sub-national jurisdictions can serve as laboratories for experimenting with innovative policy approaches, the primary motivation for China's pilot carbon-pricing systems, including in Guangdong. These were prompted by the national government, but largely implemented by

---

1 Stavins is the A. J. Meyer Professor of Energy and Economic Development at the Harvard Kennedy School, a University Fellow of Resources for the Future, and a Research Associate of the National Bureau of Economic Research. The author, who is responsible for all remaining errors, can be reached at robert_stavins@harvard.edu. This paper draws in part on Stavins (2019).

2 The principal agent problem plagues decisions regarding installation of thermal insulation or other energy-efficiency technologies in renter-occupied properties. Even with what would otherwise be an effective and appropriate carbon price in place, it is in the interest of neither the lessor nor the lessee to purchase and install adequate insulation. Hence, other — possibly sub-national — policies are called for, in this case local building codes or zoning that specify standards for insulation in new construction.

provincial and municipal governments. In general, approaches at the provincial and municipal level that prove successful on cost-effectiveness or other evaluation criteria could later be adopted at the national level. China's national government has indeed drawn on provincial experience in designing its national system, which will begin true implementation in 2021. Like some of the pilot systems, China's national system is a set of tradable performance standards, rather than an emissions-trading system with an absolute cap.

In principle, the diverse set of policy instruments that are available at the national level to reduce CO_2 emissions are also available to sub-national jurisdictions: performance standards, technology standards, and carbon-pricing instruments, including both carbon taxes and emissions trading systems. There is widespread agreement among policy analysts that economy-wide carbon pricing will be a necessary (though not sufficient) component of any policy for achieving meaningful CO_2 reductions in a cost-effective manner (Metcalf 2009; Kaplow 2010; Borenstein *et al*. 2019). Given the diversity of CO_2 sources in many economies, conventional technology and performance standards would be infeasible and, in any event, excessively costly (Newell and Stavins 2003). The key advantage of pricing instruments is the flexibility they provide and the incentives they foster for achieving cost-effectiveness in aggregate (Knittel 2019). In addition, pricing approaches can reduce long-term abatement costs by inducing climate-friendly technological change (Newell, Jaffe, and Stavins 1999).

International experience suggests that the merits of carbon-pricing systems have been well-recognized. To date, 61 carbon-pricing policies have been implemented or are scheduled for implementation worldwide, including 30 carbon taxes and 31 emissions trading systems (Figure 1). Together, these carbon-pricing initiatives will cover about 22 percent of global GHG emissions (World Bank Group 2020). All 189 parties[3] to the Paris climate agreement have submitted emissions-reduction pledges; of these, more than half indicate they will use carbon pricing.

2. KEY U.S. EXPERIENCE WITH SUB-NATIONAL CO_2 CAP-AND-TRADE SYSTEMS

There has been significant experience with two sub-national GHG cap-and-trade systems in the United States: the Regional Greenhouse Gas Initiative (RGGI), a downstream CO_2 electricity-sector cap-and-trade system in 10 northeastern and middle Atlantic U.S. states; and the AB-32/398 Cap-and-Trade Program in California.

With RGGI, the states were required to auction a minimum of 25 percent of their allowances, but all of the states quickly trended towards 100 percent auctions. Initially there was no true safety-valve on costs (in which the government offers additional allowances at an established price), but instead a trigger price was set at which increased use of offsets from outside of the system would be allowed. The cap was set to limit emissions to the average of the 2002-2004 level during the period 2009-2014, but this cap was non-binding, due to the modest nature

3 At January 9, 2021. The United States will likely re-join the Paris Agreement in early 2021, bringing the number of parties back to 190.

of the target, low natural gas prices (which reduced the dispatch of coal-fired electricity on the grid), economic recession, and energy conservation.

In response, the RGGI states lowered the overall cap by 45 percent in 2015, and then 2.5 percent per year after that, for an eventual 10 percent cut by 2020, which translates to 13 percent below 1990, and — more importantly — 35 percent below business as usual (BAU) emissions. A price (and cost) ceiling was imposed through a "Cost Containment Reserve" of allowances, which was equal in size to 10 percent of the cap in any year, and with a trigger price that increased annually. A price floor was established via an "Emissions Containment Reserve," through which allowances would be withheld from the market when and if price were to fall below an escalating trigger price. Despite the fact that the cap was non-binding in the earlier period and close to the price floor in the second period, hence providing only limited direct emissions impact, the allowance auctions have raised considerable revenue for the states — in excess of $2 billion.

RGGI states conducted a review of the system in 2017 and adopted a new cap reduction of 30% in 2030, relative to the 2020 cap. Annual cap reductions within this decadal target are determined by a rather complex formula.[4]

Under the Global Warming Solutions Act of 2006 (AB-32), California established an ambitious policy to cut GHG emissions to their 1990 level by the year 2020, and subsequently under AB-398 extended this to cut emissions to 40 percent below their 1990 level by 2030. Elements of this broad-based policy include: energy efficiency standards for vehicles, buildings, and appliances; renewable portfolio standards; a low carbon fuel standard; and a cap-and-trade system.

The cap-and-trade system is well designed, with a cap that covers approximately 85 percent of the state's emissions and declines from 2012 through 2030. Increasing use of auctions is employed over time, and a price collar — combining a price ceiling and price floor — is in place. The ceiling and floor escalate over time. Threats to competitiveness (emissions, economic, and employment leakage to other jurisdictions) are addressed via an output-based updating allocation used to protect energy-intensive trade-sensitive industries. Costs are also controlled through protocols for out-of-system offsets, but permission to employ these has been reduced over time from 49 percent to only 5 percent of emissions reductions.

Finally, a link has been established between California's cap-and-trade system and a nearly identical cap-and-trade system in Quebec, whereby emissions responsibilities can be shared (traded) across jurisdictions. Such links are important because they can provide significant reductions in compliance costs for the pair of linked jurisdictions (Mehling, Metcalf, and Stavins 2018).

4 For more information, see: https://www.rggi.org/program-overview-and-design/elements.

3. LESSONS LEARNED FROM SUB-NATIONAL EMISSIONS TRADING EXPERIENCE

A variety of lessons can be learned from previous and current experience with sub-national CO_2 cap-and-trade systems. We begin with lessons that are associated with general performance, and then turn to issues that arise when a sub-national policy is nested within a national CO_2 mitigation policy.

3.1 Lessons Regarding General Performance

First, in terms of the basics, cap and trade has proven to be environmentally effective and economically cost effective. Relatively low allowance prices have been a function of: (1) the degree of ambition of the cap; (2) the perverse effect of "complementary policies," including those targeting renewable sources of energy and energy efficiency; (3) technological change, which greatly reduced the cost of natural gas in the RGGI states; and (4) economic recession. Of course, the lower allowance prices and fewer emissions reductions that occur with cap and trade during a recession are an economic virtue; that is, they are counter-cyclical, and do not unduly burden industry when it is fundamentally unnecessary and unwise to do so.

It is clear from basic theory and validated by experience that a robust market requires a cap that is significantly below BAU emissions. Likewise, high levels of compliance require monitoring, reporting, and verification, combined with significant penalties for non-compliance. Also, it has been shown to be important for final rules to be established well before commencement of a system's first compliance period to avoid unnecessary price volatility.

A downstream, sectoral program has been employed in RGGI, but an economy-wide system has been shown to be feasible in the case of California. However, both CO_2 emissions-trading programs have been limited in scope of coverage, in contrast with textbook, upstream trading of rights associated with the carbon content of fossil fuels (World Bank Group 2016). Transaction costs have turned out to be low to trivial, particularly when compliance entities have been homogeneous, as in RGGI (Schmalensee and Stavins 2017).

Turning to specific elements of design, experience argues for systems that allow for a broad set of compliance alternatives, in terms of both timing and technological options. One of the most significant benefits of using carbon pricing — whether tax or cap-and-trade — is simply that technology and uniform performance standards are thereby avoided. Less flexible systems would not have led to the technological change that appears to have been induced by market-based instruments (Schmalensee and Stavins 2017).

Provisions for banking of allowances have proven to be exceptionally important; as such intertemporal trading has represented a large share of the realized gains from trade. In contrast, the absence of banking provisions can lead to price spikes and price collapses. More broadly, a changing economy can render a cap non-binding, as in RGGI in the past, or drive prices to excessive levels. Hence, there is a distinct role in cap-and-trade systems for price collars, which reduce the risk of unanticipated allowance price changes and price volatility by combining an auction price floor with an allowance reserve, as with both RGGI and AB-32/398. On the other hand, excessive constraints on offset use can lead to a thin market that fails to be effective for cost containment purposes, an issue that has arisen with RGGI and AB-32/398.

Simplicity is important, and transparent formulas — including for allowance allocations — are difficult to contest or manipulate, particularly if rules are clearly defined up front, without ambiguity. By avoiding any requirements for prior government approval of individual trades, uncertainty and transaction costs are reduced.

The allocation of allowances is inevitably a major political issue, because of the large distributional impacts that can be involved. A striking and important experience has been that free allowance allocation has proven to foster political support, although it means that the opportunity is foregone to cut the program's overall social cost by refunding revenues from auctioning allowances through cuts of distortionary taxes. However, empirical experience has also revealed that political pressures exist to use auction revenue not for the economist's favorite purpose of cutting distortionary taxes, but to fund new or existing government programs or relieve deficits (both with AB-32/398 and RGGI). Indeed, in these two programs, cap-and-trade-allowance auctions have generated very significant revenue for governments.

Another prominent political concern with cap-and-trade systems has been the possibility of emissions and economic leakage and related competitiveness impacts. In practice, leakage from cap-and-trade systems can range from non-existent to potentially quite serious, as with RGGI. It is most likely to be significant for programs of limited geographic scope, particularly in the power sector because of interconnected electricity markets, an issue with both RGGI and AB-32/398. Attempts to reduce leakage and competitiveness threats through free allocation of allowances *per se* does not address the problem, but an output-based updating allocation — in principle — can do so, an approach utilized in California.

Carbon pricing (whether through cap and trade or carbon taxes) may be said to be necessary to address climate change, but it is surely not sufficient, due to the limited sectoral scope of some carbon pricing regimes, and — more broadly — due to the presence of other market failures that inhibit the perfect functioning of markets. Hence, there can be an appropriate role for complementary policies. But actual suites of so-called "complementary policies" have frequently conflicted rather than complemented, by addressing emissions under the cap, thereby relocating rather than reducing emissions, driving up abatement costs, and suppressing allowance prices (Organization for Economic Cooperation and Development 2011). This perverse situation has characterized two of the most prominent applications of cap and trade in the climate policy context — the California system and the European Union Emissions Trading System.

The degree of perverse interaction of a complementary policy with a cap-and-trade system within which it is nested can be characterized by the difference in marginal abatement costs between the cap-and-trade system and the complementary policy. In the case of California, these marginal costs are known, because they are represented by the allowance price in the AB-32 cap-and-trade system, and by a separate allowance price under a distinct trading system that operates in the state's refinery-based Low Carbon Fuel Standard (LCFS). In February 2020, AB-32 allowances were trading at about $18/ton, while LCFS allowances were trading at approximately $200/ton, representing a dramatic departure from an overall system of cost-effective emissions reduction (Climate Policy Initiative 2020). However, these perverse interactions, frequently characterized as the "waterbed effect" in the European context (Fankhauser, Hepburn, and Park 2010; Perino 2018), may be partially alleviated by planned reforms employing "market stability reserves" in California and RGGI (Perino, Ritz, and van Benthem 2019).

3.2 Implications of Nesting Sub-National Policy within National Policy

What can be learned from theoretical research and U.S. experience of nesting a sub-national climate policy inside a national climate policy?[5] In the United States, the co-existence of sub-national (state) and national (federal) programs has been an ongoing feature of climate change policy. Although congressional proposals for cap and trade or other forms of carbon pricing stalled during the Trump administration, there is support in Congress and the Biden administration for increasing the stringency of federal motor vehicle fuel efficiency standards (so-called Corporate Average Fuel Economy or CAFE standards). And there is ongoing interest in a "national renewable electricity standard" (RES), which would mandate that a given share of an electric company's production come from renewable sources (most likely wind power) or, in the case of a "clean energy standard" (CES), from an expanded list including nuclear and hydroelectric power. At the state level, there is considerable climate policy activity as well, with climate policies contemplated, developed, or implemented by more than half of the fifty states.

The co-existence of national and sub-national policies raises questions about how these policies will interact. In the presence of national policies, to what extent will sub-national efforts be cost-effective? And how does the co-existence of sub-national and national policies affect the ability of sub-national efforts to achieve emissions reductions beyond those implied by national policy?

3.2.1 Problematic Interactions from Overlapping Regulations

Some important interactions stem from the overlap of national and sub-national regulations. Such interactions apply to two pairs of U.S. national and sub-national policies: state-level RES/CES and national RES/CES; and California's fuel-efficiency standards and national CAFE standards.

3.2.1.1 Renewable Electricity/Clean Energy Standards

Under the typical design of a RES or CES, generators earn tradable certificates or credits for each unit of renewable or clean energy they produce. At the end of the accounting period, each firm must surrender certificates equivalent to its required level of renewable/clean energy production, defined as a specified share of its total production. Among the 30 states with such programs,

5 This part of the paper draws on Goulder and Stavins (2011).

most had targets of 15 percent to 20 percent of total electricity production by 2020. Some, such as California, had targets as high as 33 percent. Previous proposals in the U.S. Congress for a national RES have ranged from a target of 3 percent to 15 percent

A renewable electricity standard with trading is closely related to the cap-and-trade approach to pollution control. Many sub-national RES programs are intended as climate policies. Hence, these can be thought of as CO_2 emissions trading systems where the difference in carbon intensity among the three fossil fuels — coal, petroleum, and natural gas — is ignored and (depending upon the treatment of other fuel sources) the zero-carbon properties of hydro and nuclear are ignored. The disregard for differences in carbon content limits the cost-effectiveness of the RES. Cost-effectiveness is also compromised because the RES does not directly put a price on the externalities associated with fossil-based electricity generation; instead it focuses on the ratio of renewable- to fossil-based generation.

In assessing the implications of overlapping regulations, the simplest case to think about is where the national RES (or CES) embraces all entities or activities covered by those states that are also adopting an RES.[6] Suppose the national policy is in place, and a state introduces a policy that is more stringent than the national one — in the sense that it requires reductions from sources within the state that are greater than would be achieved under the national program alone. How does this affect emissions reductions *nationwide*, as well as cost-effectiveness?

The answer depends on whether the national program includes provisions for trading national renewable energy credits. Consider the case where the national program includes such provisions — which is the case with existing proposals. And suppose that, prior to the imposition of the "green" state's tighter requirement, a firm was just meeting the national requirement. In this case, by increasing its commitment to renewable electricity to comply with the tighter green state requirement, this firm will have more than met the national requirement. It now has excess national renewable credits and can sell these credits to firms operating in states with a less stringent state-level RES (or none at all). By purchasing these excess credits, firms in other states will not need to rely as much on renewable-sourced electricity.

Under these circumstances, emissions leakage could approach 100 percent: the increase in renewable electricity and the reduction in emissions achieved in the green state could be largely or fully offset by reduced renewable electricity and increased emissions in other states. Moreover, the green state's efforts cause a worsening of the cost-effectiveness of the nation's overall emissions-reduction efforts. In the absence of the green state's RES, the national program would cause marginal abatement costs to be equated across states and sources. The green state's action now eliminates this equality, leading to higher marginal abatement costs in that state than in other states. Thus, overall costs rise with very little or no accompanying reduction in nationwide emissions. The same problems would arise if the national program allowed a firm with

6 Where national and state policies involve imperfectly overlapping coverage, the interactions depend upon which policy is more comprehensive in its scope of coverage, and which is more stringent for the sources covered by both policies. On this, see: Goulder and Stavins (2010).

operations in more than one state to meet the national standard by averaging its performance across sub-national jurisdictions with tighter and more lax state-level requirements.[7]

In principle, there are two ways in which this leakage can be avoided. One is for the national government to allow a state or group of sub-national jurisdictions a "carve out" from the national program if they implement or maintain a sub-national program (or programs) at least as stringent. There is abundant precedent for this in U.S. policy. The result would be two separate and distinct fuel-efficiency or RES/CES programs, with the national system applying only to sub-national jurisdictions that do not carve themselves out. The shadow price on fuel-efficiency and the price of renewable credits will be different in some sub-national jurisdictions than in the national system, and so cost-effectiveness will still be compromised.

Another way to avoid these problematic interactions is through national rules that preempt (that is, essentially, prohibit) state-level programs in the presence of a national program. There is precedent for this approach as well. In this way, leakage is prevented, as well as the attendant loss of cost-effectiveness. Also, this is a way of assuring that private industry does not face multiple standards. However, to the extent that a greener state's actions raise costs, those costs are borne by that state alone; therefore such sub-national jurisdictions might oppose preemption on the grounds that sub-national jurisdictions should have the freedom to decide whether to impose higher costs on themselves.

An alternative national design would not allow trading, that is, involve no provision for renewable energy credit trading at the national level. But a primary virtue of trading is to encourage increased use of renewable energy sources where it is cheapest to do so. The alternative design would not have this virtue, and would sacrifice cost-effectiveness. In this case, there is no longer a channel through which a firm facing a new and tighter state-level standard can reduce pressure on the national constraint by selling excess national credits. Here the more stringent green state standard does not cause emissions leakage to other states; hence it yields a reduction in nationwide emissions. However, a tightening of the national standard instead of a tighter requirement in an individual state could accomplish the same reduction in emissions at lower cost.

3.2.1.2 Motor-Vehicle Fuel Efficiency Standards

Nested national and sub-national regulations lead to similar problems in the context of automobile fuel-efficiency standards or limits on greenhouse gas emissions per mile. By 2009, fourteen states had moved to limit GHG emissions per mile. These so-called "Pavley standards" (named after the key sponsor of the California legislation) required manufacturers to reduce per-mile GHG emissions by about 30 percent by 2016 and 45 percent by 2020 (California Air Resources Board 2008).

---

7 This result of near-100 percent leakage and the related cost-effectiveness outcomes are analyzed in more detail by Goulder and Stavins (2010). Similar outcomes apply in the context of a federal cap-and-trade system (McGuinness and Ellerman 2008; Burtraw and Shobe 2009; and Goulder and Stavins 2010).

Since CO_2 emissions and gasoline use are nearly proportional, the Pavley standards effectively raised the fuel economy requirements for manufacturers in the states adopting the limits. These state-level actions were quantity-based regulations that can interact significantly with the existing Corporate Average Fuel Economy (CAFE) standards at the national level. Consider an auto manufacturer that prior to the imposition of the Pavley limits was just meeting the CAFE standard. Now it must meet the tougher Pavley requirement through its sales of cars registered in the adopting states. In meeting the tougher Pavley requirements, its overall U.S. average fuel economy exceeds the national requirement: the national constraint no longer binds. Hence, the manufacturer is able to change the composition of its sales outside of the Pavley states; specifically, it can shift its sales toward larger cars with lower fuel-economy.

Indeed, if all manufacturers were initially constrained by the national CAFE standard, the introduction of the Pavley requirements would lead to emissions leakage of 100 percent at the margin, because the reductions within the Pavley states would be completely offset by emissions increases outside of those states. Empirical estimates indicate that from 2009 through 2020, about 65 percent of the emissions reductions achieved in the new car market in the Pavley states would be offset by increased emissions in new car markets elsewhere (Goulder, Jacobsen, and van Benthem 2012).

In May 2009, the Obama administration reached an agreement with the fourteen Pavley states, according to which the U.S. would tighten the national fuel economy requirements in such a way as to achieve effective reductions in GHGs per mile consistent with the Pavley initiative. In return, the fourteen states agreed to abandon the Pavley effort, which was no longer necessary, given the tightening of the national standards.

Despite this potential for leakage, the tougher state-level standards could conceivably accelerate the development of new technologies that auto manufacturers will eventually adopt throughout the nation, thereby leading to lower emissions and reduced fuel consumption. However, in the presence of the national CAFE standard, faster technological progress exacerbates the adverse fleet compositional impacts of sub-national programs (Goulder, Jacobsen, and van Benthem 2012). As a result, in this case, greater technological progress yields relatively little benefit in terms of reduced fuel consumption.

3.2.1.3 Price-Based Policies

The problematic interactions identified above are specific to national quantity-based regulations — whether market-based, such as cap-and-trade or renewable energy standards, or command-and-control, such as technology or performance standards. The situation is very different with national price-based regulations. Suppose, for example, that a carbon tax was imposed at the national level. If a state decided to impose new regulations requiring in-state reductions beyond what the national tax would yield, the additional state-level reductions would not lead to offsetting increases elsewhere (apart from the usual economic leakage that results when the marginal cost of producing carbon-intensive goods and services differs across jurisdictions): the reductions in other sub-national jurisdictions would remain governed by the national carbon tax. Thus, price-based regulation at the national level can avoid the problem of 100% leakage, despite the regulatory overlap. However, the greener state's more aggressive action would not achieve nationwide reductions in the most cost-effective way: the same aggregate reductions could be achieved at lower cost with a relatively small increase in the national carbon tax rate.

3.2.2 Potentially Positive Interactions

State and national policies can interact along other dimensions, which may lead to positive outcomes. First, strategic interactions can arise between sub-national jurisdictions and the national government. In particular, sub-national efforts can create pressure for more stringent national policy. There is, in fact, a considerable history of California air standards having this effect on national policy developments, partly because industry is reluctant to face different standards in different parts of the country. For example, the California-led state-level tightening of greenhouse-gas-per-mile standards helped bring about the subsequent tightening of national CAFE standards. Automakers did not wish to face different standards at the national and state level. Hence, they were willing to support tighter national standards so long as the state standards were removed. Of course, such triggering of stronger national policy is desirable only if the previous national policy was insufficiently stringent.

Second, sub-national jurisdictions can serve as laboratories for experimenting with innovative policy approaches, the primary motivation for China's pilot systems, including in Guangdong, which were prompted by the national government, but largely implemented by the provincial governments. In general, approaches that prove successful on cost-effectiveness or other dimensions could later be adopted at the national level. The interaction is one of information transfer. However, the case for such sub-national experimentation needs to be considered carefully: why the laboratories should be at the sub-national, rather than the national level is not clear, and — in any event — there is some question regarding whether sub-national authorities will allow their "laboratory" to be closed after the experiment has been completed and the information delivered.

3.2.3 Sub-National Actions When There is No Overlap with National Policy

When sub-national and national efforts do not overlap, the problems from nested regulation do not apply. In these circumstances, sub-national jurisdictions can fill the regulatory gap. For example, as noted above, sub-national jurisdictions may address market failures not confronted by national policy, such as the principal-agent problem of inadequate incentives — even in the face of efficient energy prices — for either owners or occupiers of rental properties to invest in energy-efficiency technologies, such as thermal insulation. This market failure is best addressed through building codes or zoning, both of which are probably better implemented at the sub-national level, because of geographic differences in climate.

More broadly, the case can be made for sub-national policy when action that arguably is best taken at the national level is simply not politically feasible. Since the externality from greenhouse gas emissions transcends national boundaries, climate change ideally should be addressed at the global level. However, just as political and institutional obstacles to a "world-government" initiative make national policies the best available option, so too can political obstacles to national efforts leave room for sub-national efforts.

3.3 Nesting Sub-National Policy within a National Tradable Performance Standard

When a sub-national policy is nested within a national policy that features averaging of quantities, such as cap-and-trade, the interactions between those policies can be problematic, benign, or positive. When the national policy is instead a tradable performance standard (TPS), as in the case of China's national system to be launched in 2021, the consequences are similar to the situation with a national cap-and-trade system, but more complex.[8] The consequences are the same for those cases leading to benign and positive interactions, but somewhat different for cases leading to problematic interactions.

First, as a reminder: with cap-and-trade, if a nested (sub-national or sectoral) policy is more stringent, there is 100% leakage. But under a TPS, the leakage due to a complementary policy can exceed 100%. How can this be? The fundamental reason is that under a TPS system, the quantity of allowances distributed is endogenous to the compliance entities' outputs. In general, the stringent sub-national policy causes a reduction in the intended output of affected compliance entities (companies), because of the increase in marginal costs (assuming the firm is a profit-maximizer, that is, not a state-owned enterprise or otherwise restricted by regulation). But the attendant increase in output price can lead to greater output more broadly, and so the total number of allowances and emissions can increase in aggregate.

If the sub-national policy (or sectoral policy) is more stringent for a compliance entity (firm) than what the national TPS would have accomplished, then the firm must reduce its emissions intensity and/or purchase more allowances per output unit. Either way, the firm's marginal cost (of producing its output) increases, and so if it is a profit-maximizing firm, its output is reduced. This reduction in output by the sub-national (or sectoral) source, can lead to an increase in the price of output (throughout the economy, depending upon the scope of the market for the relevant product), which will be particularly significant if the source faces inelastic demand, such as in the electricity market. And in the national market, this output price increase can then lead to greater aggregate output — and so, given the constraint imposed by the tradable performance standard — greater aggregate emissions, which will be particularly significant if national output supply is highly elastic.

In summary, with a national TPS in place, policy interactions with a sub-national (or sectoral) policy can result in emissions leakage greater than or less than 100%, essentially because the allocation of allowances is endogenous (not fixed) under a tradable performance standard. If the sub-national elasticity of supply is greater than zero, but equal to zero everywhere else, then there

8 This section draws upon: Goulder and Morgenstern (2018); Goulder, Long, Lu, and Morgenstern (2020); and personal communications with Lawrence Goulder (2020).

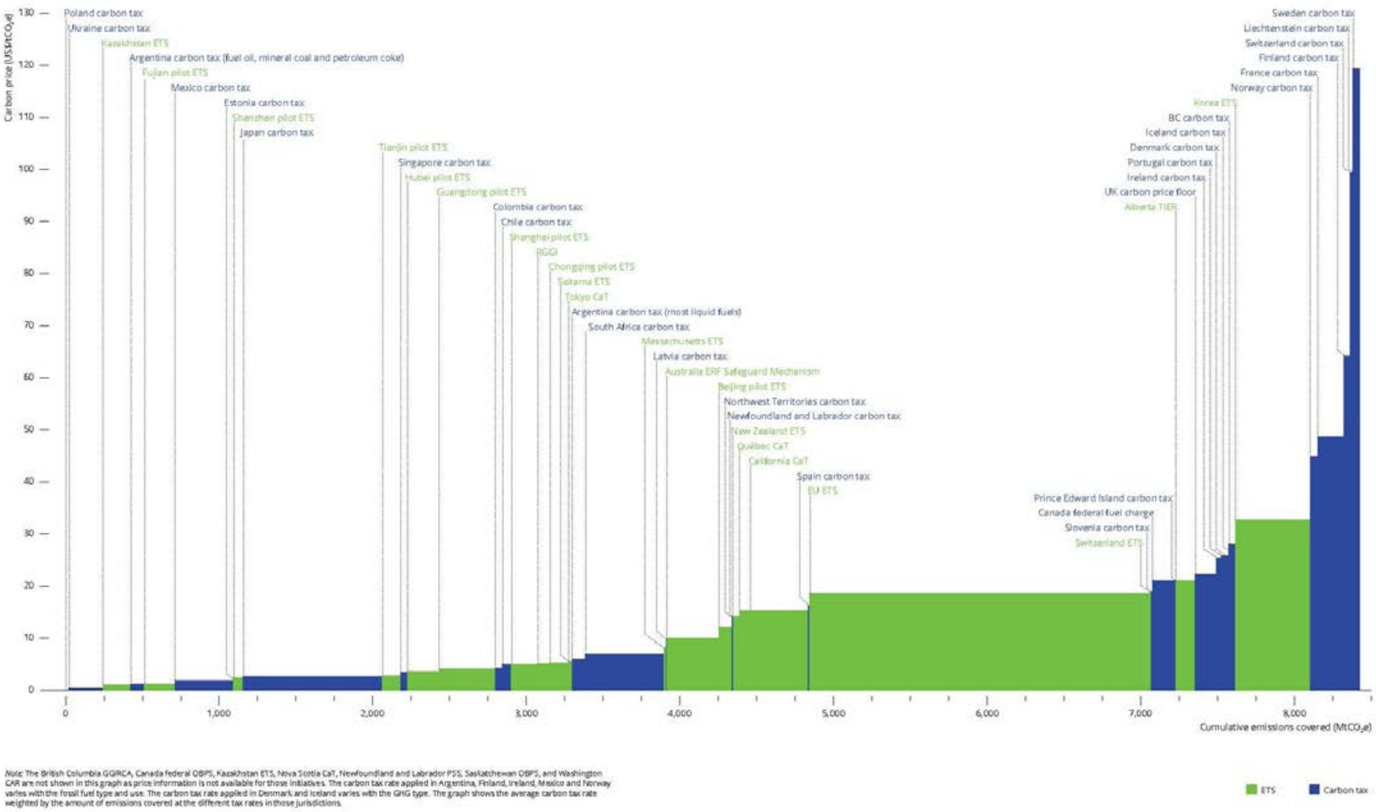
is no leakage. If the supply elasticity is greater than zero everywhere else, but not exceptionally high, then leakage will exist, but less than 100 percent. And if the national supply elasticity is particularly great, leakage can exceed 100 percent.

4. CONCLUSION

Given the global commons nature of the climate change problem, international cooperation is essential, and the highest levels of effective governance — typically countries — should be involved as the key jurisdictions to implement effective GHG mitigation policies. However, if national government action is inadequate or if other market failures prevent national policies from being effective, then there are potential roles for sub-national climate policies, whether those be performance standards, technology standards, or carbon-pricing instruments, such as carbon taxes or cap-and-trade systems.

A review of experiences with sub-national cap-and-trade systems in the United States, including the Regional Greenhouse Gas Initiative and California's AB-32/398 trading system, provides a diverse set of lessons for the design and general performance of emissions trading systems. Beyond this, theory and experience of nesting sub-national climate policies within a broader, national climate policy indicate that the interactions between the two levels of governance can be problematic, benign, or positive, depending upon the nature, design, and stringency of both the national and the sub-national policies. Of particular concern are situations where the national policies are based on averaging of quantities of emissions, such as with cap-and-trade systems. When the national system is a tradable performance standard, as with China's national system planned for launch in 2021, the consequences are similar to those with cap-and-trade, but decidedly more complex.

Figure 1: Carbon Price and Emissions Coverage of Implemented Carbon-Pricing Initiatives



Note: The British Columbia GGIRCA, Canada federal OBPS, Kazakhstan ETS, Nova Scotia CaT, Newfoundland and Labrador PSS, Saskatchewan OBPS, and Washington CAR are not shown in this graph as price information is not available for those initiatives. The carbon tax rate applied in Argentina, Finland, Ireland, Mexico and Norway varies with the fossil fuel type and use. The carbon tax rate applied in Denmark and Iceland varies with the GHG type. The graph shows the average carbon tax rate weighted by the amount of emissions covered at the different tax rates in those jurisdictions.

SOURCE: World Bank Group 2020, p. 27

REFERENCES

Borenstein, Severin, James Bushnell, Frank A. Wolak, and Matthew Zaragoza-Watkins. 2019. "Expecting the Unexpected: Emissions Uncertainty and Environmental Market Design." *American Economic Review* 109(11): 3953-3977. https://doi.org/10.1257/aer.20161218

Burtraw, Dallas, and Bill Shobe. 2009. "State and Local Climate Policy under a National Emissions Floor." Working Paper 09-54. Resources for the Future and University of Virginia. https://www.rff.org/publications/working-papers/state-and-local-climate-policy-under-a-national-emissions-floor

California Air Resources Board. 2008. "Comparison of Greenhouse Gas Reductions for the United States and Canada under U.S. CAFE Standards and California Air Resources Board Regulations: An Enhanced Technical Assessment."

Climate Policy Initiative. 2020. "California Carbon Dashboard." https://calcarbondash.org (Accessed November 20, 2020).

Fankhauser, Samuel, Cameron Hepburn, and Jisung Park. 2010. "Combining Multiple Climate Policy Instruments: How Not to Do It." *Climate Change Economics* 1(3): 209-225. https://doi.org/10.1142/S2010007810000169

Goulder, Lawrence H., Mark R. Jacobsen, and Arthur van Benthem. 2012. "Unintended Consequences from Nested State and Federal Environmental Regulation: The Case of the Pavley Greenhouse-Gas-per-Mile Limits." *Journal of Environmental Economics and Management* 63: 187-207. https://doi.org/10.1016/j.jeem.2011.07.003

Goulder, Lawrence, Xianling Long, Jieyi Lu, and Richard Morgenstern. 2020. "China's Unconventional Nationwide CO_2 Emissions Trading System: Cost-Effectiveness and Distributional Impacts." Working Paper, August. https://www.dropbox.com/s/8gmlakkerip1puw/China%27s%20Unconventional%20Nationwide%20CO2%20Emissions%20Trading%20System%20-%2020%20Aug%20%2720.pdf?dl=0

Goulder, Lawrence, and Richard Morgenstern. 2018. "China's Rate-Based Approach to Reducing CO_2 Emissions: Attractions, Limitations, and Alternatives." *American Economic Review Papers and Proceedings* 108: 458-462. https://doi.org/10.1257/pandp.20181028

Goulder, Lawrence H., and Robert N. Stavins. 2010. "Interactions between State and Federal Climate Change Policies." National Bureau of Economic Research Working Paper 16123. https://www.nber.org/papers/w16123

Goulder, Lawrence H., and Robert N. Stavins. 2011. "Challenges from State-Federal Interactions in U.S. Climate Change Policy." *American Economic Review Papers and Proceedings*, 101(3): 253-257. https://doi.org/10.1257/aer.101.3.253

Kaplow, Louis. 2010. "Taxes, Permits, and Climate Change." National Bureau of Economic Research Working Paper No. 16268. https://www.nber.org/papers/w16268

Knittel, Christopher R. 2019. "Diary of a Wimpy Carbon Tax: Carbon Taxes as Federal Climate Policy." Working Paper 2019-013. MIT Center for Energy and Environmental Policy Research, August. http://ceepr.mit.edu/publications/reprints/707

McGuinness, Meghan, and A. Denny Ellerman. 2008. "The Effects of Interactions between Federal and State Climate Policies." Working Paper 08-004. MIT Center for Energy and Environmental Policy Research, May. https://dspace.mit.edu/handle/1721.1/45518

Mehling, Michael A., Gilbert E. Metcalf, and Robert N. Stavins. 2018. "Linking Climate Policies to Advance Global Mitigation." *Science* 359(6379): 997-998, March 2. http://doi.org/10.1126/science.aar5988

Metcalf, Gilbert E. 2009. "Market-Based Policy Options to Control U.S. Greenhouse Gas Emissions." *Journal of Economic Perspectives* 23(2): 5-27. http://doi.org/10.1257/jep.23.2.5

Newell, Richard G., Adam B. Jaffe, and Robert N. Stavins. 1999. "The Induced Innovation Hypothesis and Energy-Saving Technological Change." *Quarterly Journal of Economics* 114: 941-975. http://doi.org/10.1162/003355399556188

Newell, Richard G., and Robert N. Stavins. 2003. "Cost Heterogeneity and the Potential Savings from Market-Based Policies." *Journal of Regulatory Economics* 23: 43-59. https://doi.org/10.1023/A:1021879330491

Organization for Economic Cooperation and Development. 2011. *Interactions Between Emission Trading Systems and Other Overlapping Policy Instruments*. Environment Directorate, OECD. https://doi.org/10.1787/5k97gk44c6vf-en

Perino, Grischa. 2018. "New EU ETS Phase 4 Rules Temporarily Puncture Waterbed." *Nature Climate Change* 8(4): 262-264. https://doi.org/10.1038/s41558-018-0120-2

Perino, Grischa, Robert A. Ritz, and Arthur van Benthem. 2019. "Understanding Overlapping Policies: Internal Carbon Leakage and the Punctured Waterbed." National Bureau of Economic Research Working Paper 25643. https://www.nber.org/papers/w25643

Schmalensee, Richard, and Robert N. Stavins. 2017. "Lessons Learned from Three Decades of Experience with Cap and Trade." *Review of Environmental Economics and Policy*, 11(1): 59-79. http://doi.org/10.1093/reep/rew017

Stavins, Robert N. 2019. "The Future of U.S. Carbon-Pricing Policy." National Bureau of Economic Research Working Paper 25912. https://www.nber.org/papers/w25912

World Bank Group. 2016. *Emissions Trading in Practice: Handbook on Design and Implementation*. Partnership for Market Readiness and International Carbon Action Partnership. https://openknowledge.worldbank.org/handle/10986/23874

World Bank Group. 2020. *State and Trends of Carbon Pricing*. https://openknowledge.worldbank.org/handle/10986/33809.

Harvard Project on Climate Agreements

79 John F. Kennedy Street
Cambridge, Massachusetts 02138, USA

+1 617 496 8054
climate@harvard.edu
www.hks.harvard.edu/hpca