Local Solutions to Global Problems: Climate Change Policies and Regulatory Jurisdiction

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Introduction

This article considers the efficacy of various types of environmental regulations when they are applied locally to pollutants whose damages extend beyond the jurisdiction of the local regulator. For example, within the United States, many of the efforts to adopt policies to mitigate climate change are taking place at the local level. A number of states (e.g., California, New Jersey, New York, Oregon, Rhode Island), impatient with what is perceived as inadequate federal action, have adopted various controls to address climate change. At the same time, many US cities have adopted climate change policies, as evidenced by the over 700 mayors who have signed the US Conference of Mayors Climate Protection Agreement. Indeed, the growing market for voluntary carbon offsets, purchased by individuals, can be viewed as the ultimate local action. Further, the global nature of the climate change problem means that even actions taken by individual countries can face the same types of problems as those experienced by cities or states.

Unfortunately, local regulations of a global pollutant may be ineffective if producers and consumers can avoid them by transacting outside the reach of the local regulator. In many cases, this may involve the physical relocation of the economic activity, a problem often referred to as "leakage." This paper highlights another way in which local policies can be circumvented: through a reshuffling of who buys from whom. Reshuffling is a concern when buyers are subject to regulations (i.e., downstream regulation). While leakage can be costly, as, for instance, when firms relocate their production, with reshuffling, neither the location nor the costs of production need change.

We maintain that the problems of reshuffling are exacerbated when the options for compliance with the regulations are more flexible. The very flexibility that makes market-based regulations, such as cap-and-trade, attractive, can also make them susceptible to

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We are grateful to Max Auffhammer, Dallas Burtraw, Alex Farrell, Larry Goulder, Dan Skopec, and Rob Stavins for helpful discussions and comments.
Review of Environmental Economics and Policy, volume 2, issue 2, summer 2008, pp. 175–193
doi:10.1093/reep/ren007
Advance Access publication on June 3, 2008

circumvention if only applied locally. In contrast, where leakage is concerned, the cost impacts of regulation matter more than the flexibility of the mechanism. We argue that leakage problems are more pronounced with regulations that impose a cost on firms than with subsidies designed to reward production from nonpolluting sources.

Ironically, the tools that offer local regulators the greatest potential to make real progress toward an environmental goal may be among the least attractive from an economic efficiency perspective when considering regulation on a large scale. In particular, targeted subsidies for "clean technologies," although vulnerable to political favoritism and limited in flexibility, can have a measurable impact on pollution. Therefore, although local subsidies for energy efficiency, renewable electricity, and transportation biofuels constitute attempts to pick technology winners, they may be the only mechanisms that local jurisdictions, acting alone, have at their disposal to address climate change.

The article proceeds as follows. The next section discusses various regulatory tools, which we divide into two broad categories: those that impose costs on the polluting entities and those that subsidize "clean" behavior or technologies. In the third section, we discuss the vulnerability of these regulatory tools to the issues of leakage and reshuffling. The fourth section explores in detail the issues of leakage and reshuffling using specific examples of state-level climate change initiatives in the United States. We focus particularly on the electricity sector, which has been one of the main targets of early efforts to mitigate climate change, in part because it accounts for more CO_2 emissions than any other sector of the US economy. We also present numerical analyses demonstrating that several proposed policies to limit greenhouse gas emissions from the California electricity sector may have very little effect on carbon emissions if they are applied only within that state. The last section summarizes our findings and concludes.

Policy Options

In this section, we describe the broad spectrum of policy options for regulating environmental pollutants and briefly discuss the relative merits of these policies. We distinguish between policies that impose costs on emitters and those that subsidize activities that regulators deem desirable. Of course both types of policies involve a component of revenue redistribution. For example, subsidies to some customers or firms must be paid for by someone, and "costly" regulations such as emissions taxes or cap-and-trade can generate revenue windfalls that can be redistributed in many ways. Later we argue that the two types of regulations have different implications for local jurisdictions.

Cost-imposing regulations

One traditional approach to an environmental problem is to enact policies that cause firms to internalize the negative externalities created by their emissions. This can be achieved using several different regulatory tools, including technology mandates, environmental standards, and market-based regulations. These policies require firms to either take costly mitigation actions or forgo profitable, but polluting, activities. As a result, these regulations all impose an implicit (or explicit) tax on the polluting activities of firms. They can also vary in the flexibility they allow for compliance.

Command and Control Regulations: Technology Mandates and Standards

We begin by describing the least flexible regulatory tools—technology mandates and environmental standards—which are often referred to as command-and-control regulations. Technology mandates dictate specific technologies (the *how* of environmental regulations) and the set of firms that must adopt the technologies (the *who* of an environmental improvement strategy). For example, under the New Source Performance Standards in the US, new plants built in counties that are in attainment with the National Ambient Air Quality Standards must install the Best Available Control Technology (BACT). In practice, the BACT is essentially determined through case-by-case negotiations between the firm and the Environmental Protection Agency.

A slightly more flexible type of command-and-control regulation is an output-based environmental standard, such as a maximum limit on the emission of a pollutant or on the energy usage of an appliance. In some cases, each source of emissions (e.g., a power plant, an appliance) is required to comply with the standard, but it is left to the producer of the polluting product to determine the most cost-effective way to achieve compliance. In other cases, standards are applied over multiple sources, such as a standard on the average emissions across all of a firm's plants. For instance, under the Tier 2 vehicle emissions reduction program in USA, automobile manufacturers must achieve a fleet average emission rate of 0.07 grams of NO_x per mile. Subject to this constraint, firms may determine the exact emissions rate for any given vehicle model as well as the particular technology they will use to achieve that rate.

If mandates or standards are enforced broadly, they can be very effective at achieving an environmental goal. So long as the standards are binding, firms and consumers will alter their behavior, for instance, by installing pollution control equipment that they otherwise would not or by purchasing more efficient appliances than they would have. The standards will then result in lower emissions within the jurisdiction where they are imposed. Regulators can determine with minimal monitoring and enforcement costs whether firms are complying with the standards.

In general, command-and-control regulations have been criticized by economists as an inflexible and inefficient approach for dealing with environmental problems. The main criticism of regulatory mandates and standards has been that they are much more costly than necessary, in terms of both the costs to the firms and the foregone consumer welfare of people who would otherwise consume a product that has been banned or made more expensive by the regulatory standard. This is because all firms are required to meet the same standard. If there is heterogeneity across firms, for instance in their production processes or in the vintage of their capital, it may be relatively inexpensive for some firms to achieve substantial emissions reductions, while for others it may be prohibitively costly to achieve any reduction in emissions. In short, one-size fits-all standards do not recognize the potential differences in compliance costs across the regulated sources, and therefore cannot take advantage of these differences. The severity of this problem is obviously closely related to the actual size of those cost differences. Unfortunately, it is often difficult to know exactly how much costs will vary before the regulations are put into place.

Market-Based Regulations

The most flexible forms of cost-imposing regulations are market-based policies. These include taxes on emissions or programs that allow the government to limit emissions by issuing permits that can be traded among polluters (known as "cap-and-trade"). Rather than dictating the technology (*the how*) or even the specific emissions of a facility or firm (*the who*), these programs use price signals to provide incentives to firms to reduce emissions in the most cost-effective way possible.

An emissions tax places an explicit charge on each unit of pollution produced by a firm or individual.[1] If a firm has options for reducing its emissions that are less expensive than the tax itself, then it should adopt those options and reduce its emissions. Importantly, one of the options likely to be considered is simply consuming less of the input that is producing the pollution (e.g., fuel, fertilizer, chemicals). Thus taxes, in a relatively straightforward fashion, can directly and appropriately impact both production and consumption choices in a market.

An alternative market-based policy is a cap-and-trade regulation of pollution quantities.[2] A cap-and-trade system imposes an overall regional limit on total emissions (the cap) but allows flexibility as to which sources within that region actually emit. Emissions permits or credits, totaling no more than the regional cap, are created and allocated to the regulated firms. In theory, firms that can cheaply reduce their emissions will sell credits to firms that find it very expensive to reduce (the trade). The net result is that the emissions target is achieved in a way that minimizes overall costs. Note that regardless of whether a firm is buying or selling permits (and regardless of whether the initial allocation of permits was given or sold to a firm), polluting under a cap-and-trade system entails a marginal cost that is equal to the market price of the permits. In other words, for each additional ton of pollution emitted, net buyers of permits must purchase an additional permit, while net sellers incur a cost equal to the lost opportunity to sell another permit.

Because of their inherent flexibility, these policies are attractive in circumstances in which they can be practically applied. They do not require a perfectly informed regulator to develop the optimal carbon-reducing strategy. In theory, individual firms will arrive at the least-cost method for reducing their emissions because, under most circumstances, they have an incentive to do so.[3] Regulators still play a central role in a market-based system, as the parameters they set for the regulatory instruments will drive firms' decisions. However, their role is more limited than under other regulatory approaches.

[1]Nordhaus (2007) discusses many of the advantages of taxing carbon emissions rather than setting quantity limits through something like a cap-and-trade policy.

[2]Dating back to Weitzman (1974), there is a rich literature in environmental economics on the proper use of "price" tools such as emissions taxes vs. "quantity" tools such as command and control regulations or emissions caps. The general idea is that taxes help to limit uncertainty over the costs of compliance while quantity regulations help to limit the uncertainty over how much pollution results.

[3]There are cases where a firm's incentives may not be strictly aligned with minimizing its compliance costs. For example, a regulated utility may prefer options that can be added to its rate base (see Fowlie 2006).

Subsidy Programs

Next we describe policies that attempt to regulate pollutants through the carrot of financial subsidies rather than the stick of emissions limitations. In the policy arena, the promotion of "clean" technologies has been a popular alternative to limitations on the use of "dirty" technologies. The promotion of clean technologies can be accomplished through direct subsidies for the manufacture or installation of the technologies, tax incentives, or mandates that buyers procure a certain percentage of their consumption from clean sources.[4] As with cost-imposing regulations, subsidies can vary in their regulatory flexibility, ranging from an inflexible subsidy on specific technologies to a more market-based approach in which the subsidy increases in proportion to the positive externalities associated with goods.

Consider first an example of a direct subsidy for a particular clean technology. Many states provide refunds to homeowners who install solar photovoltaic cells to produce low-emissions electricity. The subsidy can also take the form of a requirement that a certain share of purchases be from low-emissions sources. For instance, California has adopted a low-carbon fuel standard (LCFS), which requires a reduction in the average carbon content of transportation fuels. Several other states are actively considering an LCFS, and there are some proposals for a national low-carbon fuel standard. Here, since the focus is on the mix of transportation fuels sold, rather than on reducing consumption of transportation fuels, an LCFS is largely a subsidy for ethanol and other low-carbon fuels. Which particular low-carbon fuels will be used to meet an LCFS will be determined by market competition between the fuel producers.

Proponents of subsidies often point to a variant of the "infant industries" argument. This hypothesis, often applied in the context of international trade, argues that certain technologies or industries would be very competitive with incumbent technologies if they could capture the necessary economies of scale or learning. Thus, the subsidies promoting these technologies speed up their development, moving the industry along the learning curve faster, or allowing it to grow to a minimum efficient scale more quickly. Once these technologies reap the benefits of such efficiencies, no further intervention is necessary. These new technologies will, in theory, continue to be preferred even if the environmental costs of the old technologies are not borne by the producers.

It is important to note that even the presence of a strong potential for learning or scale economies does not necessarily cause a market failure. The key issue is whether those economies can be appropriated, through patents or a dominant position in the market, or whether there are significant knowledge "spillovers." If a firm can profit from developing a new technology, there is a market incentive to innovate. If the innovations are easily copied by competitors, investment in research and development becomes a public good, thereby justifying public support.

There have been several criticisms of "green" subsidies. First, although it is perhaps more politically appealing to make clean technologies cheaper than to make dirty sources more expensive, such an approach sends the wrong message to consumers. Subsidies impose

[4]Note that here we are drawing a distinction between mandates or standards imposed on consumers that implicitly subsidize producers using clean technologies, from mandates imposed directly on producers (i.e., the users of dirty technologies), which we discussed in the previous subsection.

no additional costs on continued consumption from dirty sources. The opportunity for encouraging conservation in the obvious way, by making the production more expensive, is therefore lost. In practice, the cost of direct subsidies is often borne by other customers, which means that at least indirectly, dirty consumption can be made more expensive. Similarly, subsidizing a source that is less bad than the alternative still promotes consumption of the "bad." For example, in the context of the LCFS, although encouraging a transition from petroleum-based fuels to biofuels can reduce the greenhouse gas (GHG) impact of each mile traveled, the production of biofuels themselves still creates GHGs.[5] Thus, by subsidizing the consumption of biofuels, the policy could actually lead to *higher* GHG emissions.[6]

A second, related criticism of "green" subsidies is that they will indirectly reduce the prices for dirty products by drawing demand away from them. From a consumer perspective this may sound appealing, but from the perspective of an environmental regulator, lower prices for dirty products are counterproductive. Even if consumption of the disfavored product is discouraged within the region where the subsidies are applied, lower prices will encourage consumption elsewhere.[7] Therefore, when applied locally, even subsidies of alternative energy sources are not immune to spillovers in other regions.

The overall effect of a local subsidy will be a function of the relative price impacts of those subsidies on the "clean" and "dirty" goods, and the elasticity of demand for those goods in other regions. When adopted by small jurisdictions, these price impacts are likely to be small. It is worth pointing out that command and control mandates, as discussed previously, can also have an indirect effect on prices for the dirty goods. Specifically, when a locally applied standard causes firms to adjust production, for example by relocating plants, the cost of production will go up because the standard has forced firms to make suboptimal decisions. If these higher costs are passed on to consumers, demand for the dirty product will fall. For small jurisdictions, these spillover pricing effects are likely to be small and even negligible. However, from a practical perspective, local regulators need to determine whether the price impacts of a policy produce less damaging spillovers than the leakage and reshuffling effects.

Perhaps the biggest drawbacks of targeted subsidies are the practical barriers to implementing them effectively. Even with skilled and dedicated regulators, the information required to pick the "right" technologies is daunting. So there is considerable risk that large subsidies will go to technologies that would not prove competitive under ideal regulations. Politicians and regulators are in effect placing large bets that the expected economies of scale and learning will in fact materialize. Even when these benefits do not appear, there are often calls for continued subsidies, preventing some "infant" industries from ever growing up.

There is no question that politics also play an important role in the subsidies game. For example, many argue that USA's focus on corn-based ethanol has been significantly influenced by the Midwestern farm-belt (see Gardner 2007; Wall Street Journal 2007). Federal tax incentives for the purchase of hybrid-fuel cars were deliberately designed to favor those

[5]For ease, we use biofuels as an example of a transportation fuel that generates lower carbon emissions than petroleum products. However, questions have recently been raised about whether using ethanol in fact leads to lower carbon emissions (Searchinger et al. 2008).

[6]See Holland, Knittel, and Hughes (2007) for a detailed examination of this point.

[7]This phenomenon is sometimes referred to as demand-side leakage, which we discuss in more detail in the next section. It is worth noting that a reduction in natural gas prices has been cited as a benefit of aggressive adoption of renewables (see Wiser, Bolinger, and St. Clair 2005).

producers who sell hybrids in smaller volumes, who also happen to be US auto manufacturers. Of course, it could be argued that politics plays a role in just about any regulation or public policy. However, because subsidies often involve direct transfers of money to certain parties, they appear to be even more vulnerable to these pressures than other regulations. Moreover, once subsidy programs are set in place and are conferring direct benefits to specific groups, it becomes politically difficult to remove them.

Problems with Local Application of Environmental Regulations

Based on the discussion in the last section, from an efficiency perspective, market-based regulations are more appealing than less-flexible regulations or subsidies. However, when one is considering the local regulation of a global pollutant, such as GHGs, the situation becomes more complicated. This section discusses the problem of circumvention, specifically leakage and reshuffling, when environmental regulations and policies are applied locally.

Leakage

Perhaps the most obvious way for polluters to circumvent an environmental regulation is to relocate the regulated facility and its polluting activities to another jurisdiction. Following the literature, we refer to this physical relocation of facilities as *leakage* (see, for example, Fowlie 2007 and Kuik and Gerlagh 2003). There is also the phenomenon of demand-side leakage, whereby a local regulation that depresses demand for a polluting goods in one region can lead to higher quantities demanded of the goods in unregulated regions (see Felder and Rutherford 1993). We will focus here on supply-side leakage, although we comment on the relationship between demand-side leakage and reshuffling when we discuss reshuffling below.

When differentially applied across regions, mandates and standards can lead to leakage. For example, under the Clean Air Act (CAA), more stringent and costly emission standards apply to nonattainment areas. Research has demonstrated that industrial activity declines in nonattainment areas and is at least partially displaced by growth in attainment areas, where regulation is less costly (see Greenstone 2002 and Becker and Henderson 2000). To the extent that this displaced production emits at higher, less regulated rates, pollution has leaked from the heavily regulated region to the more lax region.

Market-based regulations are equally vulnerable to the problems of leakage. For example, if one jurisdiction imposes a tax on emissions or establishes a cap-and-trade system, it will be more expensive for firms to produce their pollution-intensive goods. This creates an incentive for firms to move some of their production elsewhere. They may accomplish this by producing slightly less from their regulated plants and more from their unregulated plants, or by moving their particularly pollution-intensive plants out of the regulated region.

When considering the leakage of polluting sources away from areas of stringent regulation, it is critical to recognize the varying impacts of local pollution. For example, many of the CAA criteria pollutants cause damage close to where they are emitted, with the classic example being ground-level ozone, which contributes to smog. Therefore the relocation of polluting sources is not necessarily a bad outcome (see Becker and Henderson 2000).

However, the relocation of polluting sources may not improve the local environment. This may be the case if the plants move "upwind" of the regulated region, or if the region applying the standard is very small relative to the geographic scope of the environmental problem. In this regard, climate change represents the most extreme and challenging case. This is because the location of GHG emissions does not influence their impact on the climate. When it comes to climate change, everywhere is upwind. The global public good aspect of the climate is therefore one of the great challenges to formulating climate change policy (see Nordhaus 2007). To the extent that local regulations cause outmigration or "leakage" of regulated facilities, rather than a true reduction from local sources, the local environment will not improve.

Until now, we have not distinguished between standards imposed on firms, such as emissions limits for plants, and standards imposed on individuals, such as energy efficiency standards for homes. While leakage is possible with both types of standards,[8] leakage is generally less likely to be a problem at the individual level largely because trying to avoid the standard can be more costly than meeting it. For instance, few people choose to live in Nevada instead of California simply to avoid the residential energy efficiency standards in California.

Despite all the potential disadvantages of targeted subsidies, they do have the advantage of being less vulnerable to leakage. Because they do not impose costs on firms, firms have no reason to relocate production to avoid them. To the contrary—subsidies are often touted as a way to attract new firms or even industries to benefit the local economy. Therefore, smaller jurisdictions, such as US cities or states, may find subsidies more appealing than other regulatory tools that can be more easily circumvented. In fact, subsidies may be the only means to meaningfully impact emissions on a local level.

Reshuffling

We now turn to a related problem that can arise when regulations are imposed at the point of purchase, but where some consumers are subject to the policies and others are not.[9] If a sufficient percentage of the products affected by a regulation already complies with it, the policy's goals can be achieved by simply reshuffling who is buying from whom. This will make the policy completely ineffective, as it will not alter the rate at which the favored product is produced. For example, assume that California accounts for 10 percent of the world sea bass market, and that it adopts a regulation stating that only sea bass caught using sustainable fishing techniques can be sold in the state. If more than 10 percent of sea bass in the world market is *already* caught using sustainable techniques, these fish can be diverted for sale in California. So, even if Californians had previously been consuming some nonsustainable

[8]For example, homeowners may build just outside a local area to avoid zoning restrictions, or consumers may purchase on the Internet in order to avoid local sales taxes.

[9]Ironically, policy makers are often attracted to consumer-based regulations either because much of the production takes place outside of their jurisdiction or because they fear that regulating only producers within their jurisdiction will lead to leakage.

fish, their ban will have no effect on the way fish are caught worldwide as long as consumers outside of California are indifferent between sustainable and nonsustainable fish.[10]

As the above example demonstrates, the reshuffling problem is similar to the conditions that limit the effectiveness of consumer boycotts. Although a percentage of motivated customers stops buying from the boycotted source, there will be no net impact on sales or prices if there are enough other price-sensitive customers who are indifferent to the cause of the boycott and willing to shift to the boycotted producers. As with an ineffective boycott, reshuffling is more likely when the share of products that already comply with a policy is larger than the share of consumers who are subject to it.

Note that both reshuffling and demand-side leakage affect demand outside the regulated area. Unlike demand-side leakage, however, reshuffling does not change total equilibrium consumption (or prices or emissions) of the regulated goods. Reshuffling requires that consumers inside the regulated region perceive the clean product to be a perfect substitute for the dirty product, and so substitute all their consumption to the clean product, while consumers outside the regulated region are indifferent between consuming clean or dirty goods, and so increase their consumption of the dirty goods. There is no such perfect substitute available with demand-side leakage. In fact, there is a duality between reshuffling and demand-side leakage, since if firms are able to reshuffle completely, there need be no change in prices and therefore no demand-side reaction to the regulation. It is only to the extent that firms are unable to avoid the regulation through reshuffling that there is a real reduction in emissions in the regulated jurisdiction through new, clean supply or reduced dirty consumption. In the latter case, there could be demand-side leakage if the reduced dirty consumption in the regulated region drives down the price for the product elsewhere.

California's attempt to set fuel economy requirements on vehicles sold within its borders (through AB 1493 and associated court challenges) provides an example of the potential for reshuffling under a regulatory standard. The standards would require higher fuel economy than is required at the federal level under the Corporate Average Fuel Economy standards. If California succeeds, the policy will encourage car manufacturers to sell less fuel-efficient vehicles in other parts of the country than they would have sold otherwise and yet still meet national standards, which are based on national average fuel economy. This could result in a reshuffling of car sales and not necessarily a real reduction in emissions (see Stavins, Jaffe, and Schatzki 2007).

There are conditions under which a policy such as a California fuel economy standard could have a meaningful impact on the national fleet. Specifically, if a jurisdiction is large enough, a local standard may force an industry beyond a tipping point, where it is less costly to produce all goods, even those sold outside the regulated region, to comply with the local standard. In this case, the local standard, far from being bypassed, actually gets leveraged onto other regions. In a related fashion, previous California regulations to limit pollution from vehicles have often led, in due time, to the adoption of equally stringent regulations at the national level. Some observers credit the California regulations with demonstrating to car manufacturers and federal regulators that lower emissions can be achieved relatively cost effectively.

[10]The result that reshuffling will have no effect on market equilibrium assumes that there are no transaction costs associated with rematching buyers and sellers.

Similarly, indirect subsidies, which promote clean technologies by requiring consumers to purchase them, can be vulnerable to reshuffling. Consider the case of the LCFS as implemented by California. In assessing the carbon content of various transportation fuels, the California LCFS takes a lifecycle approach by tracking the environmental impact of fuel production up the supply chain. For example, ethanol produced from lower-carbon crops and using lower-carbon farming methods would earn more credit under the California proposal than dirtier ethanol. Similarly, gasoline refined from light crude oil would receive a slightly higher credit (or lower penalty) than gasoline refined from heavy crude oil. If the California policy favors clean ethanol, then consumers in other states will buy the dirty ethanol previously purchased by Californians. If California's demand for clean ethanol under the LCFS is less than the existing supply of clean ethanol, this policy will have no impact on ethanol farming practices.

A consumption-based application of cap-and-trade can also fall victim to the reshuffling of production. In the next section we discuss in detail an example of this problem in the context of the California electricity sector. Reshuffling is not just a problem with a cap-and-trade system—it can also occur under an emissions tax, as long as the tax is levied on consumers and not producers. For instance, if gasoline consumers in California were charged higher prices for gasoline refined from carbon-intensive sources such as heavy crude oil or oil sands, producers would have an incentive to divert products from lower carbon sources to California.

Barriers to Leakage and Reshuffling

Clearly, regulatory jurisdiction can cause serious problems when environmental regulations are applied locally to pollutants, such as GHGs, whose damages extend beyond the jurisdiction of the regulator. We have argued that subsidies, in particular targeted subsidies, are less vulnerable to leakage or reshuffling. However, it is important to note that transaction costs and other barriers can influence the extent to which buyers and sellers can circumvent local policies.

A key consideration concerning leakage is the cost of changing the physical source of production. Assuming that production was sourced efficiently prior to the imposition of environmental regulations, any change in that production would involve some increase in costs. These costs could range from an increase in transporting goods, to the physical relocation of entire production facilities. Constraints on import capacity, such as pipeline, transmission line, or port-facility capacities, can limit the feasibility of leakage. In many cases these costs may exceed the costs of the environmental regulation, making leakage unprofitable.

The transaction costs of reshuffling appear to be less severe as reshuffling does not involve the relocation of production; it simply rearranges where products are shipped. Assuming that transportation costs were minimized before the implementation of the policy, reshuffling would only increase the costs. This could be true of attempts to favor different sources of ethanol under a LCFS for example. Electricity provides a special case since electrons cannot be tracked to particular generators. As a result, reshuffling in the electricity sector is more of a financial arrangement than a physical activity.

Institutional factors, such as overlapping government regulations or limitations, may also reduce the extent of reshuffling and leakage problems. For example, electricity sales from federally owned water projects in the US favor certain customer classes, and it may prove difficult for these customers to resell their subsidized power. In the specific context of climate change policies, many of the large emitters of GHGs are either regulated or government-owned. The strong influence of government on those firms' decision making can limit their incentive or ability to execute leakage or reshuffling strategies.

That said, as we describe below, the problems of leakage and reshuffling are of more than academic concern when it comes to local GHG policies. If states act unilaterally, without the participation of other states in their regions, these problems could seriously undermine the impact of the regulations.

Climate Change Policies for the Electricity Sector

In this section, we describe specific regulatory policies aimed at reducing carbon emissions from the electric power sector. We focus on the experience in California because it has adopted a wide range of policies, but we also discuss initiatives in other regions of the country. In each case, we assess the potential for leakage and reshuffling.

Emissions Standards

California senate bill 1368 establishes a standard for emissions from plants providing "baseload" power to "load-serving entities" (LSEs), the firms responsible for either producing or purchasing electricity for end-users in California. The law requires that new energy purchases and investments by California LSEs be directed exclusively towards low-carbon power plants.[11] In Bushnell, Peterman, and Wolfram (2007) (hereafter BPW 2007), we demonstrate that there are already ample resources outside of California that comply with this emissions standard. California utilities can comply with the standard by buying from the existing low-carbon sources, and leaving new or old "dirty" sources to meet the demand from other states (see BPW 2007).

Efficiency standards can have a meaningful effect if they apply to choices that are inherently local—such as residential and commercial building and lighting standards—where leakage is not a serious issue. In fact, California has had a long tradition of enacting energy efficiency standards for homes and appliances. For this reason, and because California's standards have often been adopted at the national level, its energy efficiency program has likely had a meaningful impact on emissions from the electricity sector (see Geller 1997).

Subsidies

Regulators have adopted a wide variety of initiatives to encourage specific alternative energy technologies for producing electricity. For illustrative purposes, we will focus our discussion

[11] Specifically, the law requires that power plants that LSEs invest in, build, or buy power from under long-term contract must meet a standard that limits their emissions to be no greater than those from a current combined-cycle natural gas plant.

on two prominent programs that represent different implementation philosophies: state-level renewable portfolio standards and the California Solar Initiative (CSI).

As of this writing, 27 states and the District of Columbia have adopted renewable portfolio standards. While the details of their implementation vary, these policies share the common characteristic that they impose a requirement that electric utilities within the state meet a certain percentage of their demand with energy from renewable sources. Conceptually, a renewable portfolio standard (RPS) does not target a specific technology, but rather a class of technologies, for preferential treatment.[12]

In theory an RPS could be subject to reshuffling. For example, if California imposed an RPS, and significant amounts of renewable supply already existed in the western states, California utilities could comply with the RPS by purchasing from existing sources. In practice, the policies have been, and seem likely to continue to be, strongly binding regulations that are dramatically changing the procurement practices of electric utilities. This is because the renewable capacity necessary to meet states' RPS obligations does not yet exist. While many of the policies call for renewables to account for 15 percent or more of electricity sales, only California and Maine currently generate more than 10 percent of their power from renewables. With so many states enacting an RPS, the option to comply by exporting dirty power and importing the renewable energy from other states is limited.

While the RPS favors all renewables, several states and cities have adopted policies to promote specific alternative energy sources. Perhaps the most ambitious of these in USA is the CSI. The initiative is a set of direct subsidies to property owners who install solar photovoltaic systems on their buildings.[13] Over the next 10 years, the program will allocate up to $2.8 billion in subsidies, financed from general electric rates. The program represents a classic example of a targeted subsidy, and is generally immune from leakage and reshuffling. Californians have clearly been responding to these subsidies. In the first year of the investor-owned-utilities' CSI program, which is responsible for 65 percent of the total state target, more new solar were scheduled to be installed (210 MW) in California than in the previous 26 years combined (CPUC 2008a).

However, as often happens with targeted subsidies, some have questioned whether the California regulators were wise to invest so much money in this particular technology. Proponents of the CSI program claim that an expansion of solar PVs in California will spur new efficiencies in their design, production, and installation and local economic investment in the industry (see Jurgens 2006; US Newswire 2006). Critics, on the other hand, have pointed out that an injection of even several hundred million dollars per year into the worldwide solar PV market (estimated at over $5 billion), while significant, would hardly constitute the dramatic, transformational change in demand necessary to capture needed efficiencies (see Borenstein 2008). Moreover, at current costs, current-generation solar PV seems a curious technology to bet on. Even generous estimates indicate that solar PV installations cost about 30 cents/kWh, many times the current costs of coal-powered, natural-gas-powered, or even

[12]RPS policies in fourteen states do require some portion of the RPS to be met with a specific technology, but these amounts are small relative to the total RPS requirement.

[13]The original subsidy was adopted by the California Public Utilities Commission. In 2006, Senate Bill 1 extended the program to most municipal utilities.

wind-powered electricity generation.[14] If the anticipated efficiency benefits of these subsidies do not materialize, the energy procured under this program could be four to five times costlier than other alternatives.

Market-Based Regulations

Currently, two areas of the country are considering using cap-and-trade programs to regulate GHG emissions from the electricity sector: a consortium of 10 northeastern and mid-Atlantic states, organized as the Regional Greenhouse Gas Initiative (RGGI), and California. When it begins operations, RGGI will be the first US mandatory cap-and-trade program to control carbon dioxide emissions, with the goal of reducing emissions by 10 percent below 2009 levels by 2018 (Regional Greenhouse Gas Initiative 2007a). California's GHG legislation, AB 32, articulates an overall goal of reducing California's GHG emissions to 1990 levels by 2020. Unlike RGGI, the scope of the California legislation extends well beyond the electricity industry to include most major sources of GHG emissions.

There are two possible approaches to measuring the amount of emissions from the electricity industry: a consumption-based metric and a production-based metric. RGGI has adopted a production-based approach and California appears to be leaning toward a hybrid production- and consumption-based approach. This hybrid approach would regulate imported electricity through a consumption-based system and local sources through a production-based system (CPUC 2008b). It is instructive to consider the possibilities for leakage and reshuffling under the two systems.

Since some of the RGGI states participate in markets with generators outside of the cap-and-trade program, concern has been raised about emissions leakage under a production-based system (Northeast Regional Greenhouse Gas Coalition 2005; RGGI Emissions Leakage Multi-State Staff Working Group 2007b). Debate persists regarding the extent to which such emissions leakage will occur, particularly since the magnitude will be affected by location-specific factors and allowance prices. Modeling projections, however, estimate potential emissions leakage of 18–27 percent through 2015, meaning that for every 100 tons of CO_2 reduced from plants within RGGI, 18–27 tons will move to unregulated states (RGGI Emissions Leakage Multi-State Staff Working Group 2007b).

A pure production-based standard has never really gained traction in California, presumably because a substantial fraction of California's electricity and a majority of the GHG emissions come from plants outside of California.[15] Therefore, reducing emissions to 1990 levels only from plants within California would not accomplish as much in terms of emissions levels as a similar reduction in emissions from all plants that sell to California. Also, there is a significant risk that a production-based standard could be circumvented by simply increasing

[14]See Borenstein (2008). At the residential level, these costs are further subsidized by the practice of "net-metering," whereby generation from residential power sources can be used to offset not just the cost of utility electricity generation, but also the sunk costs of the network infrastructure, such as transmission wires and other utility operations.

[15]The accounting of production is complicated somewhat by the fact that there is coal capacity owned by (or contracted to) California LSEs that is located outside of California but connected in such a way that, electrically, it is treated as within California. In 2004, over 29 TWh of electricity generation was attributed to plants that fall in this category (McCann et al. 2006).

net imports from outside of California (i.e., leakage). Absent additional limitations, these imports would count as perfectly "clean" under a production-based standard.

However, the regulation of imports through a consumption-based approach could be significantly undermined by reshuffling, as we have demonstrated in other work (see BPW 2007). Specifically, to examine whether there is enough low-carbon capacity to meet California's GHG goals for electricity, we use a projection of California's 2020 electricity demand of about 340 terawatt-hours (TWh) (see BPW 2007 for the assumptions underlying this projection). Since the CO_2 emissions from meeting California's electricity demand in 1990 were approximately 80 million metric tons (MMT), we use this as the target for 2020.

We analyze power plant operations in the west in 2004 to determine whether it is possible to meet California's GHG goals with *existing* western electricity production, which would limit the regulation's impact on investment. In 2004, there were 265 TWh of output from zero-carbon sources, mainly large-scale hydro and nuclear plants. The emissions of CO_2 necessary to meet the remaining 75 TWh of electricity demand in 2020 ($75 = 340 - 265$) would be only 30 MMT of CO_2, well below the 1990 level of 80 MMT. This suggests that California could procure power in the western markets from existing sources without exceeding 1990 carbon emissions levels. It also implies that a consumption-based standard for California is at serious risk of circumvention if utilities in the western states reshuffle their energy sources.

These calculations reflect many important underlying assumptions about the ability and willingness of western electricity firms to trade their electricity. It is intended as an illustrative example of the potential severity of the problem, rather than a forecast of what is likely to happen. That said, BPW (2007) considers several of the most likely impediments to a complete reshuffling of energy sources,[16] and concludes that California is not large enough a player in the western electricity market to cause substantive changes with a cap-and-trade policy unless it undertakes additional regulatory intervention. Because of such concerns, California regulators have considered various administrative rules relating to the accounting of emissions from "outside" the regulated region that could reduce, or even eliminate, the incentives to reshuffle purchases. Most solutions would involve setting a default emissions value that would be used to measure emissions from imported power no matter what the source, and then limiting the ability of California utilities to claim as imports emissions from facilities whose emissions are cleaner than this default.[17] For instance, California regulators have proposed excluding existing hydro and nuclear plants from the set of sources eligible to be claimed as imported power. These rules dilute the incentives for existing firms located outside the region to actually reduce emissions. They also blunt the accuracy of emissions measurement and could draw legal challenges.

The reshuffling in the electricity sector could reduce the effectiveness of AB 32 in other sectors. If the cap-and-trade system allows trading across sectors, then electric companies

[16]The BPW (2007) analysis excludes purchases from the Bonneville Power Administration, the largest source of federally owned hydropower, and assumes that emissions from all sources within California will be counted. This could reflect regulatory constraints on reselling this power out of California to avoid AB 32 or it could reflect transmission constraints that limit imports to their 2004 levels.

[17]For example, power purchases could be tied to a historic reference year, rather than actual current purchases. Thus a firm that bought power from a coal plant in 2000, for example, would be responsible for the future emissions from that same plant, whether or not it continues to buy power from it. For more discussion, see Bushnell (forthcoming).

could sell any excess allowances they create by reshuffling. Firms in other sectors could purchase these allowances instead of actually reducing the carbon emissions from their production processes.

A far better outcome for the fate of a cap-and-trade program would be the expansion of its jurisdiction. At the end of February 2007, California Governor Schwarzenegger, together with the Governors from Arizona, New Mexico, Oregon, and Washington, announced a plan to do just that. The Governors outlined plans to establish a regional cap within six months and to set up a regional cap-and-trade system within 18 months (see Eilperin 2007).[18] With this in mind, BPW (2007) examined a policy that would include the five states that are parties to the agreement.

We find that a five-state production-based policy would likely help to induce (or reinforce) a decision to retire a few coal plants by 2020. However, the key question is: what kind of capacity would replace those plants and generate the additional energy required to meet load growth in this region? The problem again with a production-based standard is that this additional demand could be met from new facilities located outside of the five-state block. If the new plants are coal-fired, this would clearly not help to reduce GHG emissions.

Under a consumption-based standard, the imports would, in theory, be judged based upon the carbon content of their sources. There are significant amounts of zero-carbon hydroelectric capacity outside of the five states (including in Canada). In addition, if sufficient capacity is built to comply with the various RPS policies enacted by the five states, the zero-carbon energy from these sources will account for about half of our load-growth projections. This suggests that 1990 emissions levels could be met if a small amount of new zero-carbon generation were added anywhere in the west (BPW 2007).

In sum, our analysis suggests that even if carbon limits are expanded to cover Arizona, New Mexico, Oregon, and Washington, the policy tool that is likely to have the greatest impact on reducing the carbon intensity of electricity generation is the renewable portfolio standard. This highlights an important consideration in regulatory policy design—that several different regulatory instruments are often applied simultaneously. We address this topic in the next section.

The Interaction of Regulatory Options

Often, debates over the choice of the appropriate regulatory instrument fail to take into account the fact that any regulation is likely to coexist with a host of other regulations that can affect the problem of interest. This issue is particularly relevant when discussing market-based environmental regulations. The key advantage of market-based mechanisms is that they afford the regulated industry more flexibility as to how, and even how much, to comply. However, this flexibility can be greatly reduced when the market-based mechanism

[18]Growth in carbon emissions between 1990 and 2004 varied considerably from state to state. States in the Pacific Northwest showed the highest proportional increases, because a high fraction of their capacity installed by 1990 was hydro or nuclear plants, which are zero carbon sources. However, in terms of raw tonnage of carbon emissions, Arizona stands out as the state with the largest increase since 1990 (and is therefore the farthest away from a target of reducing to 1990 levels). Arizona's generation accounts for roughly half of the 42 MMT increase in carbon emissions among the five states since 1990.

is overlaid onto a series of other regulations. Nowhere is this truer than in the electricity industry, with its history of strong economic and environmental regulation.

Overlapping regulation can have both negative and positive impacts. Research has shown that the economic regulation of firms, rather than a motivation to minimize costs, can determine a firm's choice of compliance option under a cap-and-trade system (see Fowlie 2006). This can, for example, lead to investments being made in capital-intensive pollution control by firms with the most favorable regulatory treatment, rather than those with the lowest cost.

On the other hand, when the market-based regulation is applied only locally, traditional regulatory instruments can limit the leakage and reshuffling problems that would otherwise arise. Indeed, regulators in both California and the RGGI states have expressed a commitment to use energy efficiency standards and to promote alternative energy while developing a cap-and-trade system. Both regions are relying on these other measures, in part, to limit the problems of a localized cap-and-trade market (RGGI Emissions Leakage Multi-State Staff Working Group 2007b). Yet these measures, which include aggressive commitments to renewable energy and energy efficiency, as well as direct oversight of the procurement decisions of regulated utilities in their regions, will no doubt limit the impact of the cap-and-trade program. California's electricity industry may be the most extreme case, with many different regulations directed at reducing GHGs. In addition to funding for energy efficiency and an RPS target of 20 percent of energy consumed by 2010, there are also explicit penalties and laws aimed at preventing investment in new coal-fired plants. The RPS alone could account for approximately half of the growth in demand for electricity in California between now and 2020. When expected energy efficiency is included, California's RPS and energy efficiency programs will likely meet almost 95 percent of load growth, leaving compliance with AB 32 down to reducing current emissions to 1990 levels (California Energy Commission 2007a). If California pursues some of the more aggressive proposed policies—increasing RPS to 33 percent and increasing energy efficiency, demand response, and PV—then these programs alone will enable California to reach its 1990 emissions levels and be in compliance with AB32, without engaging in cap and trade.[19]

A similar trend can be observed nationwide. Existing state RPS programs are projected to meet approximately 60 percent of their state load growth between now and 2020.[20] Congress is currently debating a national RPS, with some bills proposing targets as high as 20 percent renewable generation by 2020.[21] Given current forecasts of national load growth, that level of renewable supply could meet all new demand. If such a bill were to pass, it would reduce the electric sector's compliance flexibility under any national GHG cap-and-trade system, which would most likely increase the cost of achieving a lower carbon electricity sector.

[19]The California Energy Commission's Scenario 5A, "High Energy Efficiency and Renewables in CA only," which includes such aggressive scenarios, predicts 2020 carbon emissions to be close to 1990 carbon levels (CEC 2007b, p. 130).

[20]Calculation based on state RPS targets and a demand growth rate of 1.98%.

[21]As of this writing, six national cap and trade bills were under consideration in the US Congress. On average, these bills target 1990 emissions levels in 2020. See Larsen (2007) for a comparative analysis.

Summary and Conclusions

Local regulators are at a disadvantage when they attempt to regulate emissions of pollutants such as GHGs, which are damaging even when emitted outside the regulator's jurisdiction. There is a significant risk that because of their limited scope, certain types of local policies could be undermined either through the exodus of physical plants, along with their emissions, to unregulated regions, or through a reshuffling of deliveries to customers within and outside the regulated area.

We have argued that leakage problems are most pronounced for regulations that impose costs on firms, as the firms are more likely to find it profitable to move to jurisdictions where they will not incur the costs. Firms may also move into a jurisdiction that is subsidizing clean technologies. Reshuffling problems can arise with both cost-imposing and subsidizing policies, but they are more pronounced with more flexible policies, such as a cap-and-trade system. This implies that regulatory mechanisms such as mandates or subsidies for specific clean energy sources or energy efficiency standards, although less efficient when applied on a large scale, may be the only kinds of regulations that can produce meaningful results at the local level.

In our survey of policies to reduce GHGs from the electricity sector, we have noted that local regulators are keenly aware of the potential for leakage. In several instances, concerns about leakage have caused regulators to consider regulating consumers rather than producers. Unfortunately, regulating consumers works much like a government-imposed boycott, and is only effective if the boycotting consumers make up a sufficiently large share of the relevant market. Thus, although there may be reasons for local regulators to target consumers instead of producers, avoiding leakage is not one of them.

Our analysis raises an important question. What are local regulators actually trying to achieve with their GHG emissions policies? Are the goals truly limited to forcing down the carbon footprint from activities within their jurisdiction? If so, one must keep in mind that the net GHG reductions from the policies proposed by a locality as large as California, assuming it achieves all its goals, would amount to less than 200 MMT of carbon equivalent economy-wide (see Farrell et al. 2006), while China's emissions of CO_2 alone are forecast to rise by several *thousand* MMT of carbon equivalent by 2015 (see Auffhammer and Carson 2008).

This fact makes it clear that local initiatives are largely symbolic unless they can also facilitate change beyond their local regions. Thus it is useful to consider those policies that are the most likely to have broader impacts, either by making it easier for other jurisdictions to adopt effective GHG regulations or by influencing the set of technologies that are available to reduce emissions. Here it is important to consider how generally applicable either the regulatory or technological lessons are.

For all of the reasons discussed in this article, the experiences with local regulations appear unlikely to have much bearing on their effectiveness at a broader level. For example, while a California cap-and-trade policy for the electricity industry may be easily undermined by reshuffling and leakage, these issues are much less likely to be a problem on a national level (electricity is not a globally traded commodity). But given political realities, an ineffectual California policy may make it less likely that a federal cap-and-trade policy will be adopted, even if the problems California experiences are unlikely to be replicated for a broader scale policy. Nevertheless, if local policies lead to what are effectively demonstration projects of various technologies, their successes or failures could be important first steps in adopting effective low-carbon technologies on a more global scale.

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