The Effect of Allowance Allocations on Cap-and-Trade System Performance

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Abstract

An implication of the Coase theorem is that under certain conditions, the market equilibrium in a cap-and-trade system will be cost-effective and independent of the initial allocation of tradable rights. That is, the overall cost of achieving a given aggregate emission reduction will be minimized, and the final allocation of permits will be independent of the initial allocation. We call this the independence property. This property is important because it means that the government can establish the overall pollution reduction goal for a cap-and-trade system by setting the cap and leaving it up to the legislature to construct a constituency in support of the program by allocating the allowances to various interests without affecting either the environmental performance of the system or its aggregate social costs. We examine the conditions under which the independence property is likely to hold—both in theory and in practice.

1. Introduction

The fiftieth anniversary of the publication of "The Problem of Social Cost" (Coase 1960) is an appropriate time to examine a key implication of that landmark study, which is of great importance not only for economics but for public policy as well. Our starting point is a well-known result from that article, namely, that bilateral negotiation between the generator and the recipient of an externality

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will lead to the same efficient outcome regardless of the initial assignment of property rights, in the absence of transaction costs, income effects, and third-party impacts. This result, or a variation of it, has come to be known as the Coase theorem.[1]

We focus on an idea that is closely related to the Coase theorem, namely, that the market equilibrium in a cap-and-trade system will be cost-effective[2] and independent of the initial allocation of tradable rights (typically referred to as permits or allowances). That is, the overall cost of achieving a given emission reduction will be minimized, and the final allocation of permits will be independent of the initial allocation, under certain conditions. We call this the independence property. It is closely related to a core principle of general equilibrium theory (Arrow and Debreu 1954), namely, that when markets are complete, outcomes remain efficient even after lump-sum transfers among agents.

We are interested in the independence property because of its great political importance. It is a key reason that cap-and-trade systems have been employed and have evolved as the preferred instrument in a variety of environmental policy settings.

Our primary objective is to examine the conditions under which the independence property is likely to hold. Our analysis is limited to environmental cap-and-trade systems, in which the government specifies an overall level of pollution, distributes allowances corresponding to that level, and permits those allowances to be traded.[3] Furthermore, we examine only the consequences of alternative free allocations of allowances, not the impacts of free allocations versus auctioning of allowances, a topic that has received much attention from economists (Goulder and Parry 2008).

In Section 2, we examine the theory behind the independence property, starting with the key findings from partial and general equilibrium analyses. Then, in Section 3, we identify the conditions under which independence may be violated, including when there are transaction costs, when firms have market power, and when firms are subject to differential regulatory treatment.

Section 4 provides an assessment of the independence property in past and current cap-and-trade systems: lead trading; chlorofluorocarbons (CFCs) under the Montreal Protocol, the sulfur dioxide (SO_2) allowance trading program, the Regional Clean Air Incentives Market (RECLAIM) in Southern California, eastern nitrogen oxides (NO_X) markets, the European Union Emission Trading Scheme (EU ETS), and Article 17 of the Kyoto Protocol. Section 5 concludes.

[1] As Hazlett (2009) noted, Coase was primarily concerned with the importance of transaction costs, not a world of zero transaction costs. It was Stigler (1966) who dubbed the above result the Coase theorem.

[2] Cost-effectiveness refers to achieving an overall emissions objective at the lowest cost.

[3] We do not consider systems that primarily involve offsets, in which a firm can generate emission credits from a baseline that is not always well defined. While many of the cap-and-trade systems we examine allow for offsetting of pollution from sources outside of the cap-and-trade system, we do not focus on this aspect of these regimes.

2. The Fundamentals of Cap and Trade

One textbook environmental economics problem is to design policy instruments that are efficient in the sense that they equate marginal social benefits with marginal social costs. As is well known, both taxes and cap and trade can accomplish this in principle, provided the regulator has adequate information on damages. In the absence of such information or the political will to use it, another important problem remains for environmental economics—to design policy instruments that are likely to achieve given aggregate environmental targets at the lowest cost. This is the cost-effectiveness challenge, and—again—either taxes or cap and trade can, in principle, meet it.

For some 40 years prior to Coase (1960), the sole economic response to the problem of externalities was that the externality in question should be taxed. In principle, a regulator could ensure that emitters would internalize the damages they fostered by charging a tax on each unit of pollution equal to the marginal social damages at the efficient level of pollution (Pigou 1920). Any quantity of aggregate emissions could be achieved cost-effectively through an appropriate emissions tax, because such a tax would make it in the interest of each emitter to equate the tax to its own (increasing) marginal abatement cost, with the result that marginal abatement costs would thereby be equated among emitters and achieve the necessary condition for cost-effectiveness. Whenever abatement costs differ across emitters (a ubiquitous fact of the real world), conventional command-and-control pollution policies—such as uniform performance standards and technology standards—would not be cost-effective, but a uniform Pigouvian tax would be.

Despite the theoretical merits of Pigouvian taxes, they have rarely been used, for a number of reasons. First, it is difficult to identify the appropriate tax rate, because decision makers typically do not have good information on benefits and costs. Second, political problems are introduced by the distributional consequences of Pigouvian taxes for regulated sources. Despite the fact that such systems minimize the aggregate social costs, these systems may be more costly than are comparable command-and-control instruments for regulated firms. This additional expense occurs because with the tax approach, firms pay both their abatement costs and taxes on their residual emissions (Buchanan and Tullock 1975). In practice, some of these costs will be passed on to consumers, but many firms may still be worse off under a tax.

Following Coase (1960), it became possible to think about solving the problem of pollution as one of clarifying poorly defined property rights. If resources such as clean air and water could be recognized as a form of property, whose corresponding rights could be traded in a market, private actors could allocate the use of this property in a cost-effective way. Crocker (1966) and Dales (1968) each proposed a system of transferable discharge permits that could provide such a market solution: the regulator need only designate the total quantity of emissions allowed (the cap), distribute rights corresponding to this total, and allow individual sources of emissions to trade the permits until an optimal (cost-effective) allocation had been reached.

In theory, the final allocation of the permits (and therefore the location of the emissions) would not depend on the initial allocation. This result was implicit in the work of both Dales and Crocker, because such independence follows directly from the notion that by properly defining property rights, participating firms have incentives to exploit all potential gains from trade. In such a well-functioning market, the permit price itself will not be affected by the initial distribution of permits, because the initial allocation does not affect firms' marginal abatement cost functions. Therefore, the final allocation of permits, in which no firm can be made better off by buying or selling a permit at the market price, is unaffected. Montgomery (1972) rigorously proved that transferable permits would in theory achieve a cost-effective allocation of control responsibility and would do so independently of the initial allocation of permits.[4] Following Montgomery, this result was frequently cited and extended to other contexts (Tietenberg 1985).

This independence property is of central political importance and is an essential reason that cap-and-trade systems have been employed in representative democracies, where distributional issues may be of paramount importance in mustering support for a policy.[5] In principle, the government can set the overall emissions cap—whether on the basis of economic efficiency or, more likely, some other grounds—and then leave it up to the legislature to allocate the available number of allowances among sources (locations) to build a constituency of support for the initiative without reducing the system's environmental performance or driving up its cost.[6]

Experience has validated the political importance of this property. For example, in the Senate debate over the Clean Air Act Amendments of 1990, bonus allowances were awarded to electricity generators in Ohio, which were going to incur particularly high costs because of their reliance on high-sulfur coal (Joskow and Schmalensee 1998; Stavins 1998); the result was the key support of Senator John Glenn (D-Ohio) for the legislation. This pattern should be contrasted with

[4] In particular, Montgomery (1972) showed that a cap-and-trade system defined in terms of ambient air quality at many receptor points would exhibit the independence property. Subsequent research demonstrated the independence property for a system of emissions permits (Krupnick, Oates, and Van De Verg 1983).

[5] The importance of efficient redistribution is highlighted in Becker (1983). In general, the most efficient way to buy or sell influence is by using money; yet politicians frequently do not choose that approach, because such transfers are highly visible. Allocated permits, which are a close substitute for money, appear to be a politically acceptable form of redistribution in applications ranging from environmental regulation to airport takeoff and landing slots.

[6] The choice of an environmental goal and the choice of a particular policy instrument for achieving that goal may be connected, and similarly it is possible that the choice of the cap of a cap-and-trade system may be connected with the choice of a specific allocation. In principle, taxes could also be designed in ways to address distributional concerns. For example, the legislature could exempt emissions up to some level for specific firms, thereby matching some of the distributional properties of a cap-and-trade system with freely allocated permits.

most public policy proposals—environmental or otherwise—for which the normal course of events is that the political machinations that are necessary to develop sufficient legislative support reduce the effectiveness of the policy and/or drive up its costs.

3. Conditions Affecting the Independence Property

We consider six conditions under which the independence property may—in principle—break down in a cap-and-trade system: transaction costs, market power, uncertainty, conditional allowance allocations, non-cost-minimizing behavior by firms, and differential regulatory treatment of firms.

3.1. Transaction Costs

Transaction costs arise in the exchange of goods and services and are particularly important in thin markets. In bond markets, for example, transaction costs may give rise to expanded bid-ask spreads. In cap-and-trade markets, there are three major sources of transaction costs: search and information, bargaining and reaching a decision, and monitoring and enforcement.[7]

The first source, search and information, may be the most obvious. Because of the public good nature of some information, it can be underprovided by markets. Brokers may step in to provide information about firms' pollution control options and potential trading partners and thus reduce the transaction costs. Although less obvious, the second source of transaction costs, bargaining and reaching a decision, is potentially as important. There are real resource costs to a firm involved in entering into negotiations, including time and/or fees for brokerage, legal, and insurance services. The third source of transaction costs—monitoring and enforcement—can also be significant, but these costs are typically borne by the responsible governmental authority and not by trading partners and hence do not fall within the notion of transaction costs incurred by firms.

Transaction costs can lead to a violation of the independence property. Coase's original formulation noted that the outcome of bilateral negotiation in the presence of transaction costs is affected by the identity of the exclusive property right recipient. But is the outcome independent of the initial allocation when the quantity of allocation to a source changes? This is the key question for cap-and-trade systems.

The answer is that the effect of transaction costs on the independence of the final allocation from the initial permit allocation depends on the nature of the

[7] All three sources can be thought of as representing costs resulting from lack of information (Dahlman 1979).

transaction costs present. If marginal transaction costs are constant, the final allocation of allowances is independent of the initial distribution (Stavins 1995).[8]

In the case of increasing marginal transaction costs, independence does not hold. Under such conditions, as the initial allocation of allowances to a source is increased, its equilibrium control level will be reduced, thereby increasing the departure of the posttrading equilibrium outcome from the cost-effective outcome. However, increasing marginal transaction costs are unlikely to be an important case in practice, because such costs are unsustainable: parties can simply split their transactions into smaller trades to economize.[9]

Finally, under decreasing marginal transaction costs, a theoretically important case, independence does not hold. Such transaction costs might result when brokers offer quantity discounts on their services or when there are positive information externalities at the market level. In this case, a shift in the allowance allocation away from the cost-effective equilibrium leads to a posttrading outcome that is closer than otherwise to the cost-effective equilibrium (Stavins 1995). This counterintuitive result stems from the fact that decreasing marginal transaction costs mean that there are scale economies of trading of which firms can take advantage. These theoretical results have been supported with experimental evidence from a laboratory study (Cason and Gangadharan 2003).[10]

3.2. Market Power and Market Structure

The presence of market power of a firm in the allowance market of a cap-and-trade regime can prevent the final allocation of permits from being independent of the initial distribution. If the firm with market power is a likely allowance seller, it has an incentive to act as a monopolist and hold back allowances from the market to drive up allowances prices,[11] and if it is a likely allowance buyer, it has an incentive to act as a monopsonist and buy fewer allowances to keep the price low (Hahn 1984).[12] Because trading behavior depends critically

[8] This is true apart from the limited sense discussed above, that is, the identification of an exclusive property right recipient. Also, Montero (1998) observes that this result does not hold if firms' marginal cost functions are discontinuous, as they might be if a firm is choosing among discrete technologies. In such cases, the existence of constant marginal transaction costs may preclude independence.

[9] Liski (2001) notes that the notion that increasing marginal transaction costs are unsustainable is based on the assumption that contacting new trading partners is costless. Increasing marginal transaction costs are sustainable if they are combined with sufficient fixed transaction costs between parties.

[10] If transaction costs are a function of market size—which is plausible if a thicker market results in lower costs of gathering information and greater opportunity for brokers to reduce friction in the market—then independence holds only if the pretrade allocation of permits is significantly different from the cost-effective allocation (Liski 2001).

[11] Malik (2002) shows that this dominant firm may actually choose to hold more permits than it needs, retiring the excess permits without their being used.

[12] According to Liski and Montero (2011), the independence property is not at risk in a dynamic permit market in which firms can bank allowances if the large players in the market are on the buyer side. These large buyers cannot exercise market power, because they suffer from a durable-goods monopoly problem; that is, they cannot credibly commit to keep a gap between their marginal costs and the allowance price.

on the initial allocation, independence does not hold, and cost-effectiveness is not achieved.

These results hold in the case of multiple dominant firms acting as Cournot players (Westskog 1996) and in a market with few buyer and sellers, all of which have some ability to set prices (Malueg and Yates 2009).[13] In both cases, the permit market achieves the cost-effective allocation only if the dominant firms initially receive the number of permits that leave them with no incentive to trade.[14]

The interaction of the permit market with a product market complicates the influence of market power on the final allocation of permits. For example, a dominant firm may utilize its power in the permit market to gain an advantage in its product market (Misiolek and Elder 1989) and thereby can manipulate the price of emissions permits to drive up the production costs of its rivals by forcing them to purchase less cost-effective abatement technology. In this case, the dominant firm would tend to purchase more permits (or sell less) than it would in a case in which there was no exclusionary effect in the product market.

Thus, when the dominant firm receives no permits and is a buyer on the permit market, the final distribution of permits may be closer to the efficient allocation than would obtain in a competitive market. But if the dominant firm receives a disproportionately large share of permits and is a seller, then the degree to which market power leads the ultimate allocation to depart from the cost-effective allocation is exacerbated.[15] In contrast, if the dominant firm exercises market power only in the product market and not in the permit market, the final allocation of permits will be independent of the initial allocation, but this allocation may not be cost-effective.[16]

Market structure can be important in other ways. One interesting case is

[13] Malueg and Yates (2009) also examine a market in which participants have market power and private information; the result is that the ultimate allocation is less predictable than it would be under typical circumstances, but the final allocation of permits remains a function of the initial distribution.

[14] Other variations of these basic models have been examined. Malik (2002) expands on Hahn (1984) to consider what would happen if some price-taking firms are noncompliant and suffer a penalty for noncompliance. This situation creates a greater elasticity of demand for permits, which reduces the extent to which the dominant firm can profit from its market power. Still, the cost-effective allocation is not achieved, because the dominant firm continues to exercise some market power and because noncompliant price-taking firms fail to equate their marginal abatement costs with the allowance price. Schwartz (2007) demonstrates that if permits are defined in terms of air quality space at a number of different receptor points with a different market pertaining to each receptor point, then, even with one or more dominant firms, the final allocation of permits may be independent of the initial allocation if the number of firms equals the number of markets in the ambient permit system.

[15] Eshel (2005) extends this model to encompass a firm that has market power in both the permit market and the product market and has found similar results.

[16] This result occurs because rival firms engaging in Cournot competition may be more aggressive in the output market if they have higher marginal abatement costs (and will therefore buy permits) but may decrease output production if they are more efficient (and will therefore sell permits). In equilibrium, the less efficient firms will hold a larger share of emissions permits than would be welfare maximizing (Malueg 1990; Sartzetakis 2004).

imperfections in capital markets that cause firms to face liquidity constraints. In this case, initial allowance allocations may affect the ultimate allocation of permits. Liquidity constraints may be one reason that smaller firms tend to adopt new technologies more slowly than do larger firms (Saloner and Sheppard 1995). More broadly, lack of liquidity can prevent firms from being able to minimize costs by investing in either permits or abatement technology. A firm initially allocated a relatively large number of permits will have greater liquidity, in the form of readily salable permits. Thus, allocation can affect entry and exit behavior.

3.3. Uncertainty

Uncertainty regarding future allowance prices can lead to a violation of the independence property under two conditions: limits to transferability of allowances (transaction costs) and risk aversion on the part of regulated firms. Without limits on transferability, an appropriate price for permits that incorporates their expected future value would emerge, and, absent other market imperfections, the market would clear so that the posttrading allocation of allowances would be independent of the initial distribution.

With uncertainty, firms with small initial allocations may be expected to overinvest in abatement technology in order to hedge against possible high future allowance prices, and firms with large initial allocations may be expected to underinvest in abatement technology in order to hedge against possible low future allowance prices (Baldursson and von dehr Fehr 2004; see also Ben-David et al. 2000). Laboratory experiments have provided some empirical support for these results (Betz and Gunnthorsdottir 2009).

Another way in which uncertainty may affect the final allocation of permits is also related to transaction costs. Building off the work of Stavins (1995), Montero (1998) incorporates uncertainty regarding whether a transaction, once initiated and in which costs have been sunk, can be completed. The results are similar to those described by Stavins (1995), but with uncertainty increasing the extent to which the final equilibrium will depart from the cost-effective one. Essentially, uncertainty increases the degree to which transaction costs impede mutually beneficial trades.

More broadly, if such uncertainty is endogenous and is a function of the number of permits demanded and the effort spent to attain trade approval, then for all types of transaction costs—constant, increasing, and decreasing—the tendency will be for an initial allocation further from the least-cost equilibrium to increase the departure of the ultimate allocation from the ideal one (Montero 1998). This result contrasts with that of Stavins (1995), who found that, under decreasing marginal transaction costs, economies of scale would lead an initial allocation further from the least-cost one to result in a more cost-effective ultimate allocation.

3.4. Conditional Allowance Allocations

Under a system of conditional allowance allocations, a firm's allocation in the current period is affected by its behavior in the previous period. This situation gives rise to inefficiencies, because firms no longer simply minimize their abatement costs but also take into account the profits they could obtain by receiving a larger allocation of allowances in the next period.

Although conditional allowance allocations do not strictly fit within the realm of the independence property because the government determines an allocation rule and not a specific allocation, this is an important case in which the initial allocation affects the outcome. For example, the government may assign allowances on the basis of a measure of output (such as gasoline production or electricity output) in the previous period.[17] We consider these rules because they determine the initial allocation and because they are proposed in a variety of applications.

An output-based updating-allocation rule serves as a production subsidy (Fischer 2001), which affects the posttrading allocation and thus can affect efficiency. Firms can be expected to increase production, because they can receive more permits in the subsequent period, and these increases contribute to their profits. The emissions price drives reductions in emissions intensity, but the prospect of allocations for additional production offsets (in part or in full) increases the prospect of additional costs from the emissions embodied in that production. Output-based allocation, therefore, means that emissions-intensive products have lower marginal costs than they would under ordinary free allocations, in which the full value of the embodied emissions would be embedded in the firm's marginal costs. Consequently, with higher output, to meet an equivalent emissions target, carbon prices must rise to bring about additional reductions in emissions intensity and shift abatement to other covered sectors (Fischer and Fox 2007).

The use of this allocation mechanism may be motivated by a desire to protect certain industries from adverse competitiveness effects (Houser et al. 2008) or by a desire to limit price impacts on consumers. For example, the American Clean Energy and Security Act of 2009 (H.R. 2454, 11th Cong. [2009])—the so-called Waxman-Markey legislation—employs this device for firms in energy-intensive trade-exposed sectors to limit the cost disadvantage that would otherwise shift competitiveness, economic activity, and emissions to countries without comparable regulation.

Unlike attempts to use ordinary free allocations to compensate the shareholders of firms in regulated sectors (which have no effects on behavior and no impacts on competitiveness), output-based updating allocations compensate firms in a way that lowers their marginal production costs. The allocations in H.R. 2454 to local distribution companies, which are regulated entities with the

[17] An extreme but not uncommon type of output-based updating-allocation mechanism is one in which a source loses its allocation if it closes down or receives a free allocation if it enters.

mandate to pass on the cost savings to consumers, have effects similar to those of output-based allocations.

Because product prices are kept lower than would otherwise occur, output-based allocations discourage reliance on conservation and substitution to less emitting alternative products as a means for emissions reductions. Instead, to meet the cap, there is greater reliance on technological solutions and conservation in other sectors that are better able to pass on the costs (Fischer and Fox 2007). This reliance means higher compliance costs.[18] In the absence of preexisting distortions, or if the allocations are poorly designed and inappropriately targeted, output-based allocations can reduce efficiency.[19]

Conditional allocations may become increasingly relevant to the climate change problem. Countries such as China and India may see it in their interest to build coal plants now if they believe it will be more costly to do so later or, alternatively, if they believe that their allocation of permits under a cap-and-trade regime would be increased (Kaplow 2009).

3.5. Non-cost-Minimizing Behavior

If some market participants are not cost minimizing (not equating their marginal abatement costs with the prevailing allowance price), then the final allocation of allowances will likely be a function of the initial allocation. There are a variety of potential sources of such non-cost-minimizing behavior.

An interesting case is that of public entities as market participants. The international emissions quota regime established under Article 17 of the Kyoto Protocol (United Nations Framework Convention on Climate Change, UN Doc. FCCC/CP/1997/7/Add. 1, December 10, 1997; 37 ILM 22 [1998]) allows trades in national targets (assigned amount units) among nations. But there is no reason to assume that nations are simple cost minimizers or even if they sought to be that they would have the necessary information regarding their national abatement costs to carry out cost-effective international exchanges (Hahn and Stavins 1999).

Behavioral economics provides several potential explanations for other sorts of non-cost-minimizing behavior. The endowment effect describes situations in which firms or individuals overvalue items already in their possession (Thaler 1980; Kahneman, Knetsch, and Thaler 1990). If the firms granted emissions allowances tend to value them more highly than do other firms simply because

[18] Evaluating the cost-effectiveness of output-based allocations requires an assessment of other distortions that we have not emphasized here, namely, tax interactions and the potential for emissions leakage (Fischer and Fox 2009; Bernard, Fischer, and Fox 2007).

[19] An alternative policy for addressing emissions leakage is border adjustment. In theory, border adjustment is generally superior to output-based allocation, since border adjustment enables the preservation of the conservation signal to consumers by ensuring that comparable carbon costs are imposed on all products. Many economists, however, would nevertheless prefer the option of output-based allocation, because border adjustments may be more likely than other policies to invite retaliation, which would lead to reduced trade and consequent welfare losses. But, in principal, production subsidies can invite retaliation as well, so it is not clear which approach is better in practice.

they happen to hold them, then fewer transactions will occur than would otherwise be predicted by market forces. If firms initially endowed with permits tend not to sell them, independence will not hold. Murphy and Stranlund (2007) suggest that the endowment effect may explain the low trading volumes in some cap-and-trade systems.

Status quo bias, a variant of the endowment effect, would lead to similar results. Like the endowment effect, status quo bias is a manifestation of loss aversion—in which actors consider the disutility of parting with an item as being greater than the utility associated with obtaining it (Kahneman, Knetsch, and Thaler 1991). A firm operating with such status quo bias might be expected to hold on to its initial allotment of permits simply because it has a preference for the status quo, whatever its mix of permits and abatement costs (Samuelson and Zeckhauser 1988).

Other sources of non-cost-minimizing behavior can also affect the performance of cap-and-trade markets. Even if managers wished to maximize profits, there may be such a high degree of organizational complexity in a firm that they cannot effectively do so (Tschirhart 1984). Related to this point is that principal-agent problems may cause firms not to minimize costs. A firm may continue to hold permits even if it would be more efficient to sell the permits and invest in abatement technology simply because it is administratively easier (Oates and Stassmann 1984).

In some scenarios, firms that are not generally cost minimizing might nevertheless minimize costs with respect to emissions abatement. Oates and Strassmann (1984) argue that this may be the case with the sort of managerial model of firms set forth by Williamson (1963). In this model, managerial utility includes a preference for expenditures on staff, salaries and benefits for management, and discretionary profits—the excess of actual profits over the minimum profits required. If abatement contributes nothing positive or negative to staff expenditures or managerial salaries, then firm managers will seek to maximize discretionary profits by minimizing expenditures on abatement—and will therefore act to equalize the permit price with marginal abatement costs. The independent, cost-effective allocation of permits will result.

Another reason for a firm's departure from cost-minimizing behavior is associated with regulatory compliance. Proponents of responsive regulation have argued that firms often do not make decisions on whether to comply with a regulatory scheme on the basis of simple cost-benefit calculations but rather are motivated—at least partly—by factors such as the shame associated with violating a regulation perceived to be morally valid (Parker 2006; Braithwaite 2002). Firms may comply with regulations out of a sense of civic duty and because of the pressure imposed by other actors not to deviate from established norms (May 2005). Thus, if the initial allocation of permits affects firms' perceptions of the moral validity of a cap-and-trade scheme, it may influence their decisions about whether to play by the rules and thereby affect the ultimate allocation of permits.

Finally, firms may be reluctant to engage in trading in the beginning stages of a market. For example, if a firm's managers are risk averse, they may try to meet the emission target that is implicitly defined by the initial allocations. So they would minimize costs across different plants that are part of their companies, subject to the constraint that emissions do not exceed the initial allocations. Ellerman (2000) calls this "autarkic compliance." In the early years of the SO_2 trading system, some utilities appear to have pursued this strategy.

3.6. Regulatory Treatment

If firms receive differential regulatory treatment, then initial allocations of allowances can affect equilibrium allocations, performance, and costs. State-level regulation of electricity producers, such as rate-of-return regulation, can discourage or even prevent firms from cost minimizing with respect to emissions (Hahn and Noll 1983; Tschirhart 1984; Oates and Strassman 1984). In addition, regulators may discourage trading, because of concerns about local pollution (Fullerton, McDermott, and Caulkins 1997). Finally, if a cap-and-trade system is interstate, then jurisdictions may be regulated differently. In all of these cases, the equilibrium allocation will not be independent of the initial allocation, and the outcome will not be cost-effective.[20]

Under typical rate-of-return regulation, utilities are permitted to extract only those revenues that are linked with certain costs determined by the regulator to be recoverable. Under the original cost method of rate making, a utility is allowed to retain as revenue its annual depreciation plus a certain proportion of its original expenditure on capital facilities. If permits are given out rather than sold, then the utility will not have spent anything to acquire its permit holdings, and the value of these permits will not be incorporated into its rate base. This problem is compounded by the common requirement that any gains from the sale of assets must be factored into utility prices—thus these utilities will effectively be taxed 100 percent on any revenue from the sale of permits. Utilities will, therefore, have incentives to spend money on other abatement mechanisms, a variation on Averch and Johnson's (1962) observation that regulated utilities will tend to overinvest in capital goods.

In states that calculate rates on the basis of the replacement cost method—adjusting the original cost of capital goods on the basis of inflation and technological changes—the above problems would not arise, as the market price of permits would be used to adjust the value of the utility's rate base, and thus the utility might be expected to minimize abatement costs (Hahn and Noll 1983). If the permit market spans several states, and some participants are subject to the original cost method regulation, then the cost-effective allocation will not be attained, as the lack of incentives to minimize cost will prevent the market from clearing efficiently. Further distortions are introduced if expenditures on abatement technologies are permitted to earn higher rates of return than amounts

[20] Obviously, a cap-and-trade system that restricts certain trades will violate the independence property if the restrictions are binding.

expended on emissions permits or if some abatement assets can be depreciated at a faster rate than others or treated as operating costs (Bohi and Burtraw 1992).

Problems can arise with respect to efficiency even if regulatory treatment is the same across utilities. Suppose there is free allocation for utilities in all states. This situation could lead to lower product prices (for example, for electricity) because of regulation, as noted above. These product prices will not generally reflect incremental costs (because of the nature of regulation) and will thus give rise to allocative inefficiencies (Spulber 1985). In particular, the equilibrium would be affected by how many allowances the utility sector is given directly. These problems can be addressed by allowing utilities to purchase allowances from local distribution companies, as suggested in the Waxman-Markey legislation.

Finally, regulators might conceivably take proactive steps that prevent the cost-effective allocation from being reached. If concerned about local pollution, a state regulator might implement rules that discourage the purchase of emissions permits, thus limiting the extent to which permits granted to utilities in other regions may cross political boundaries (Fullerton, McDermott, and Caulkins 1997).[21] In this scenario, the express purpose of regulation would be to ensure that independence does not hold and that firms are not allowed to increase their emissions to the amount that would be cost-effective for them and for the system as a whole.

4. Assessment of Effects of Allowance Allocation on Performance of Actual Cap-and-Trade Systems

In this section, we assess the independence property in existing and planned cap-and-trade systems. Our analysis proceeds in two ways: descriptively, by assessing the presence of the various conditions that could lead to a violation of the independence property, and statistically, by reviewing studies that test whether the final allocation of permits is affected by the initial allocation.

Market imperfections are present in most real-world markets. For example, in most markets, there are transaction costs in bringing buyers and sellers together. The question for our purposes is whether these market imperfections turn out to be important in terms of leading to significant violations of the independence property.

We review seven cap-and-trade systems: lead trading, CFCs under the Montreal Protocol, the SO_2 allowance trading program, RECLAIM in Southern California,

[21] Of course, there may be efficiency rationales for limiting trading when there is nonuniform mixing of pollutants or hot spots.

the eastern ozone transport NO_X market, EU ETS, and Article 17 of the Kyoto Protocol.[22]

4.1. Lead Trading

In 1973, the U.S. Environmental Protection Agency (EPA) began to impose regulations requiring refineries to reduce the content of lead in gasoline. In 1982, in conjunction with new, lower limits on lead content, the EPA authorized interrefinery trading of lead credits. If refiners produced gasoline with a lower lead content than was required, they earned lead credits, which could then be traded to other refineries. A major purpose of the program was to lessen the financial burden on smaller refineries, which were believed to have significantly higher compliance costs than larger ones had. In 1985, the EPA initiated a program to allow refineries to bank lead credits. In 1987, the program was terminated when the lead phasedown was completed (Stavins 2003).

The leaded gasoline phasedown is generally considered to have been a success (Kerr and Mare 1998). Part of this success has been attributed to the lack of regulatory restrictions on trading lead credits, the relatively low costs of trading, and the prior existence of markets among refineries for products such as gasoline additives (U.S. EPA 1985; Hahn and Hester 1989; Kerr and Newell 2003).

There is some evidence that transaction costs may have reduced the cost-effectiveness of the program. In a sample of 87 refineries in the period 1983–84, 20 percent of the refineries had not participated in the market at all, and this finding suggests that the market was probably not achieving the competitive equilibrium in the absence of transaction costs (Kerr and Mare 1998). Empirical analysis suggested that larger firms, and firms with a larger number of refineries, faced lower transaction costs than did smaller ones.[23]

Regulatory uncertainty may have added to the transaction costs. Refineries calculated whether they would have excess lead credits to transfer and traded these credits before they were verified by the EPA. In some cases, permits that were traded were later revealed to be invalid. Refineries, therefore, incurred additional costs through assessing the reputation of trading partners and investigating the validity of permits being sold. These costs led to a decrease in the cost-effectiveness of the program on the order of 10–20 percent (Kerr and Mare 1998).

There are two pieces of circumstantial evidence that suggest the independence property may not be supported in this application: differences in transaction

[22] In addition to these systems, we examined the Regional Greenhouse Gas Initiative but did not include it because of a lack of reliable data. We also examined four cap-and-trade systems that may be modified or implemented in the future: the EU Emission Trading Scheme as amended for 2012, the New Zealand Emissions Trading Scheme, the Australian cap-and-trade system, and the American Clean Energy and Security Act (H.R. 2454). At this point, it is too early to say whether these programs, if implemented, would likely support the independence property.

[23] Given that property rights were allocated on the basis of production, this system had features of an output-based allocation. See above.

costs across firms and absence of participation in the market by a significant fraction of firms. Still, it is not possible to reach a definitive conclusion on the basis of the data.

4.2. Chlorofluorocarbon Trading under the Montreal Protocol

The Montreal Protocol (1522 UNTS 3; 26 ILM 1550)—established in 1987 to limit emissions that damaged Earth's stratospheric ozone layer—required reductions in the use of CFCs and halons. The protocol called for a 50 percent reduction in the production of particular CFCs at 1986 levels by 1998 and froze halon production and consumption at 1986 levels beginning in 1992. Each country that signed the agreement was allowed to choose its own mechanism for limiting emissions. The United States implemented a cap-and-trade system in 1988 to help it comply with the protocol. The system placed limitations on both the production and the use of CFCs by issuing allowances that limited these activities. Because different types of CFCs have different effects on ozone depletion, each CFC was assigned a different weight on the basis of its depletion potential.

The production of CFCs was highly concentrated, with two producers—Du Pont and Allied Signal—accounting for 75 percent of domestic production and Du Pont alone holding a 49 percent market share. Because the protocol did not permit allowance trading across countries, these producers were shielded from potential international competition. There was, therefore, a real possibility that these firms might use their market power to manipulate the CFC allowance price. The EPA considered trying to dilute this potential price-setting ability by distributing production permits to importers as well as producers, but it ultimately decided to limit the allowance market to producers to minimize transaction and administrative costs (Hahn and McGartland 1989).

While the cap-and-trade program was a success (in that the limits imposed by the protocol were reached), the overall efficiency of the market is difficult to determine, because no studies have been conducted to estimate the cost savings (Stavins 2007). Because the market for CFC production was highly concentrated, however, it is possible that market power led to a violation of the independence property.

4.3. Sulfur Dioxide Allowance Trading under the Clean Air Act Amendments of 1990

The most important application in the United States of a market-based instrument for environmental protection is arguably the cap-and-trade system for regulating emissions of SO_2. Sulfur dioxide is the primary precursor of acid rain and a local pollutant with significant negative human health effects. This cap-and-trade system, which was established under Title IV-A of the U.S. Clean Air Act Amendments of 1990 (104 Stat. 2468; Pub. L. No. 101-549), was intended to reduce SO_2 emissions by 10 million tons (approximately 50 percent) below

1980 levels by the year 2000. Phase 1 of SO_2 emissions reductions was started in 1995, with phase 2 of reduction initiated in 2000 (Stavins 2003).

The program resulted in substantial cost savings relative to command-and-control regulation, with estimated annual savings ranging between $250 million and $1.6 billion, compared with an estimated $3 billion baseline (Carlson et al. 2000).[24] Of course, substantial cost savings do not imply that costs were necessarily minimized. It has been estimated that actual abatement costs exceeded the least-cost solution by $280 million in 1995 and by $339 million in 1996 (Carlson et al. 2000).[25] More than half of sources appeared not to have switched to using low-sulfur coal when it was economical.[26]

One possible explanation for deviations from the cost-minimizing outcome is the existence of transaction costs, particularly at the beginning of the program.[27] Firms initially confronted a very thin allowance market (Burtraw 1996). Transactions increased significantly over time, with the number of allowances traded doubling nearly every year during the first 3 years, an increase that is consistent with transaction costs decreasing as firms gained experience trading (Burtraw et al. 2005). By 1996, transaction costs were relatively low, with the average commission charged per trade at less than 2 percent (Joskow, Schmalensee, and Bailey 1998).[28]

Regulation may have brought about another distortion in the allowance market. Concerns were expressed that state regulatory authorities would limit trading to protect their domestic coal industries, and some research indicates that some state cost recovery rules were inefficient. One study examined the 11 states that would receive the most allowances and found that in six of these states there was a regulatory bias for utilities to pursue other means of compliance (for example, installing scrubbers or switching fuel types) in lieu of purchasing allowances (Bohi 1994). But other analysis concluded that public utility commission regulations did not substantially affect the allowance market (Bailey 1998). Subsequent research found a statistically significant relationship between a utility being subject to public utility commission regulations and its likelihood of choosing certain abatement methods in phase 1 (Amiru 2002). Regulated firms were more likely to switch to using low-sulfur coal, which was relatively costly in comparison with purchasing allowances.

Utility regulations may have contributed to uncertainty. Although the Federal

[24] Ellerman et al. (2000) report similar estimates, finding that costs of compliance were 55 percent of those that would be incurred under a command-and-control regime.

[25] Ellerman et al. (2000), in contrast, estimate that the cost of the program exceeded the least-cost solution by significantly less in phase 1 (between 3 and 15 percent in their estimate).

[26] Similar findings were reported by Swinton (2002), who examined the actions of seven coal-powered power plants in Florida from 1990 to 1998.

[27] Another possible explanation of the deviation observed by Carlson et al. (2000) may be that it is due to the use of an ex ante analysis, not an ex post analysis (Ellerman et al. 2000).

[28] Transaction costs may have been relatively low because the auctions the Environmental Protection Agency conducted in order to distribute allowances helped facilitate price discovery (Schmalensee et al. 1998).

Energy Regulatory Commission (FERC) established guidelines for accounting rules in 1993, FERC and the various state public utility commissions did not immediately set cost recovery rules, and many utilities were unsure of how allowance transactions would be treated (Burtraw 1996). Many utilities apparently felt comfortable trading allowances even in the absence of any sort of ruling (Bailey 1998). And the lack of formal guidance at the outset of the program does not appear to have impeded the development of the allowance market (Ellerman et al. 2000).

The presence of market power does not appear to have been a problem. From 1995 through 2003, the path of emissions was consistent with that expected from perfect competition (Ellerman and Montero 2007). In addition, the compliance decisions of the four largest firms in the market in the period 1995–99, which accounted for 43 percent of the total allowances granted, exhibit no evidence of market manipulation (Liski and Montero 2011).

In summary, it appears that, at least in the early years of the SO_2 cap-and-trade program, a perfectly cost-effective allocation of permits was not achieved, in part because of high transaction costs and utility regulations. But later, as trading became more frequent, transaction costs fell, and utility regulations were clarified. The subsequent market was likely consistent with the independence property.

4.4. The Regional Clean Air Incentives Market

The South Coast Air Quality Management District (SCAQMD), which is responsible for controlling emissions in a four-county area of Southern California, launched a cap-and-trade program in 1994 to reduce NO_x and SO_2 emissions in the Los Angeles area. This Regional Clean Air Incentives Market (RECLAIM) set an aggregate cap on NO_x and SO_2 emissions for all power plants, cement factories, refineries, and other industrial sources with emissions greater than 4 tons per year and employed a trading program that incorporates zonal restrictions, whereby trades are not permitted from downwind to upwind sources. The program also incorporates temporal restrictions, with the banking of permits limited (Stavins 2008).

In an analysis directly examining whether RECLAIM exhibited the independence property, the evidence indicated that it did (Fowlie and Perloff 2008). Regulators had randomly assigned firms in RECLAIM to one of two permit allocation cycles. Permit allocations were generally decreasing over time, and depending on which cycle a firm was randomly assigned to, the decline in a firm's allocation might occur either in January or in July. After an analysis employing instrumental variable procedures—and using random assignment into one of the two cycles as the instrument—there was no evidence of a statistically significant relationship between the initial and the final permit allocation (Fowlie and Perloff 2008).

At the same time, evidence suggests that RECLAIM has not achieved all of its cost-saving potential.[29] Transaction costs were present, in part because of the heterogeneous nature of firms participating in the market, with the result that the average facility had only a 20 percent probability of engaging in trade. The reduction in trading due to transaction costs has been estimated to be 32 percent (Gangadharan 2000).

These transaction costs likely decreased in subsequent years, as brokers and other intermediaries entered the market (Ellerman, Joskow, and Harrison 2003). Whereas only 28 percent of permit transactions in 1994 used brokers, by 2001 brokers were involved in 75 percent of trades (Fowlie and Perloff 2008). Transaction costs appear to be modest, as is evidenced by the high volume of trading in the market[30] and by SCAQMD's decision in 2002 to reject as unnecessary a proposal that would have established a centralized market for all RECLAIM permit transactions.

Uncertainty may also have created distortions in the permit market. One source of uncertainty resulted from the actions of a major private broker, which has been sued more than once for failing to deliver purchased emissions permits (Fowlie and Perloff 2008). The 17 amendments to the program rules between 1994 and 2006 likely contributed to firms' uncertainty regarding the permit market (Fowlie and Perloff 2008). Furthermore, there has been price volatility, with spikes in the price of NO_X permits in 2000 due to a spike in California energy prices, which ultimately required SCAQMD to remove electricity generators from the market. This price spike does not reflect a failing of RECLAIM design itself but rather flaws in California's deregulation of its electricity market (Harrison 2003).

It appears that RECLAIM functioned reasonably well. A direct statistical test of the independence property cannot reject the claim that the final allocation is independent of the initial allocation, but high initial transaction costs could have led to a violation of the independence property in the early years of the program.

4.5. Eastern Ozone Transport Nitrogen Oxide Market

Under EPA guidance, 12 northeastern states and the District of Columbia implemented a regional NO_X cap-and-trade system in 1999 to reduce compliance costs associated with the Ozone Transport Commission regulations of the 1990 amendments to the Clean Air Act.[31] Under the program, the EPA distributes NO_X allowances to each state, and states allocate allowances to sources in their jurisdictions. Sources may buy, sell, and bank allowances, although a system of

[29] One prospective analysis predicted cost savings of approximately 40 percent from the emissions trading program as compared with existing command-and-control regulation (Johnson and Pekelney 1996).

[30] By the end of 1997, permits corresponding to a total of 244,000 tons of emissions had been transferred (Nash and Revesz 2001), while as of the end of 2001, the corresponding figure was over 400,000 (Ellerman, Joskow, and Harrison 2003).

[31] Only nine of the 12 states actively participated in the program (Farrell 2001).

progressive flow controls limits the total number of banked allowances that can be used during the ozone season (Stavins 2003).

This program appears to have been successful. Nitrogen oxide emissions fell from 1.9 million tons in 1990 to 500,000 tons in 2006 (Stavins 2007). An ex ante examination estimated cost savings of between 40 percent and 47 percent in the period 1999–2003, compared with the costs of command-and-control regulation (Farrell, Carter, and Raufer 1999). At least the early phases of the market were broad and active (Farrell 2000).[32]

There is, however, some evidence that distortions may have affected the workings of the allowance market. Interviews with participants in the Ozone Transport Region revealed that firms had generally been conservative in their trading of allowances (Farrell 2003). First, they believed that there was a great deal of uncertainty in the market and were unsure of their ability to purchase and sell allowances. Second, because of market thinness, some firms thought they had some price-setting power and thus abstained from purchasing or selling allowances if doing so would affect the price (Farrell 2003). In summary, despite some concerns that arise from survey results, this market has appeared to work reasonably well and has reduced the costs of limiting emissions.

4.6. European Union Emission Trading System

In order to meet its commitments under the Kyoto Protocol, the EU adopted in 2003 the EU ETS, a cap-and-trade system for CO_2 emissions reduction. This downstream system covers about half of EU emissions from some 11,500 sources, including large sources such as oil refineries, combustion installations over 20 megawatts, coke ovens, cement factories, ferrous metal production, glass and ceramics production, and pulp and paper production. The program does not cover sources in the transportation, commercial, or residential sectors. The EU ETS was designed to be implemented in phases: a pilot or learning phase from 2005 to 2007, a Kyoto commitment period phase from 2008 to 2012, and a series of subsequent phases (Stavins 2008).

Direct statistical evidence exists in support of the independence property (Reguant and Ellerman 2008). In Spain, EU allowances (EUAs) were allocated on the basis of a function that rewards certain cleaner sources. Because of this allocation method, the endogeneity problems normally present in testing for independence could be avoided. No evidence was found that the initial allocation of EUAs had an effect on firms' production decisions.

Other evidence suggests that there have been relatively few distortions in the market for EUAs. Given the large number of sources covered by the program, few if any firms are capable of exercising market power. The largest player in the EUA market (in the trial phase) was allocated less than 6 percent of allowances. Even if the electricity-generating sector—which contained seven of the

[32] Including reductions achieved under the NO_X State Implementation Plan, nitrogen oxide emissions fell from 1.86 million tons in 1990 to .49 million tons in 2006 (Stavins 2008).

top 10 firms in terms of initial EUA holdings—were considered as a whole, there is no empirical evidence of market power (Convery and Redmond 2007).

Transaction costs also have been low. Although the EU ETS involves several nations, trading between firms in different countries has been frequent, in large part because of the presence of intermediaries in the EUA market (Ellerman 2008). Brokers entered the market even before the EU ETS went online, with futures trading beginning in 2004. And several companies, such as Point Carbon, facilitated transactions by tracking and reporting developments in the EUA market, providing information on prices for both buyers and sellers (Convery and Redmond 2007).

On the basis of these factors, we believe that this market's performance has been broadly consistent with the independence property. Distortions were introduced, however, by provisions that grant allowances freely to new entrants to the market and that require that unused allowances be forfeited by any facility that shuts down. Similar to output-based updating allocations, these provisions subsidize production and could lead to the independence property being violated (Ellerman and Buchner 2007).

4.7. Kyoto Protocol Article 17

In 1990, negotiations commenced that led to an agreement in 1992 on the United Nations Framework Convention on Climate Change (UNFCCC), which entered into force in 1994 with 190 countries as parties and established a long-term goal of stabilizing greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. In Kyoto, Japan, in December 1997, the parties to the UNFCCC agreed on the terms of what came to be known as the Kyoto Protocol. The protocol includes a provision for cost-effective implementation through a set of tradable permit mechanisms, two of which are credit programs (Joint Implementation and the Clean Development Mechanism) and one of which is a cap-and-trade system (the international trading provision in Article 17). These are provided as options that countries can employ.

The agreement was intended to result in industrialized countries' emissions declining in aggregate by 5.2 percent below 1990 levels by the year 2012. Despite the failure of the United States and Australia to ratify the protocol,[33] the agreement became effective in 2005, once the requirement that 55 Annex I (predominantly industrialized) countries, jointly accounting for 55 percent of 1990 Annex I emissions, ratify the agreement was met (Stavins 2008).

Early on, the emissions trading provision of Article 17 was hailed by many as the most effective of the three compliance mechanisms (Weyant and Hill 1999). But others noted reasons to be skeptical (Hahn and Stavins 1999). First, one might not expect the market created by Article 17 to exhibit independence and achieve cost-effectiveness, because the relevant market actors are nations,

[33] Australia subsequently ratified the Kyoto Protocol late in 2007.

not private firms. Nations, unlike firms, are unlikely to have the incentive or the capability to act in a cost-minimizing way. Hence, nations are unlikely to equate their marginal abatement costs with permit prices (Hahn and Stavins 1999). Moreover, the status of the participants in the markets as sovereign nations also provides a strong opportunity for noncompliance, as participation in the market is ultimately voluntary.

Another problem is that some participants in the Article 17 market may be large enough to manipulate permit prices to their advantage (Bernard et al. 2003). Such countries may be able to raise prices by subsidizing certain abatement technologies or lower prices by imposing a tariff on permit exports. Even if a nation were to distribute its allowances to firms within its jurisdiction, it may be able to implement policies that encourage these firms to coordinate their actions (Liski and Montero 2011).

Another concern raised with respect to Article 17 trading has been transaction costs. The protocol involves many countries with distinct characteristics and experiences with emissions abatement. One might, therefore, expect permit trade between these countries to feature significant search and information costs (Pan and Regemortor 2004). The EU ETS may be considered an efficient submarket of the overarching Article 17 permit market that helps lower transaction costs, although the existence and conduct of the EU ETS does not depend upon Article 17 of the Kyoto Protocol.

While markets established in response to the Kyoto Protocol targets, such as the EU ETS, may be relatively cost-effective, it is unlikely that final permit allocations are independent of initial allocations in the international permit market created by Article 17 itself. Problems with non-cost-minimizing behavior, strategic price manipulation, and transaction costs could be significant.

4.8. Summary of Findings

Table 1 summarizes our findings regarding empirical support for the independence property among the seven cap-and-trade systems we have reviewed. We examined both indirect (circumstantial) evidence regarding the presence and importance of these factors in cap-and-trade systems, as well as direct (statistical) evidence of the violation of the independence property. Overall, we find support for the independence property to be high in three of the systems (counting SO_2 allowance trading), moderate in two of the systems, and low in two.

5. Conclusions

What has come to be known as the Coase theorem—the assertion that under certain conditions, bilateral negotiation between the generator and the recipient of an externality will lead to the same efficient outcome regardless of the initial assignment of property rights—has had important impacts not only on environmental (and other areas of) economics but also on the development of public

Table 1
Summary of Empirical Findings Regarding the Independence Property

Cap-and-Trade System	Indirect Evidence of Possible Permit Market Distortions	Support for the Independence Property
Lead trading	Transaction costs	Moderate
CFC trading under Montreal Protocol	Market power	Low but no rigorous empirical analysis
SO_2 allowance trading	Transaction costs, differential regulatory treatment, uncertainty	Low at the outset, high subsequently
RECLAIM	Transaction costs, uncertainty	High[a]
Eastern ozone transport NO_X markets	Market power, uncertainty, non-cost-minimizing behavior	Moderate
EU ETS	Possible uncertainty	High[a]
Kyoto Protocol Article 17	Transaction costs, market power, non-cost-minimizing behavior	Low but no rigorous empirical analysis

Note. CFC = chlorofluorocarbon; EU ETS = European Union Emission Trading Scheme; NO_x = nitrogen oxides; RECLAIM = Regional Clean Air Incentives Market; SO_2 = sulfur dioxide.

[a] This conclusion is partly based on statistical tests. Only those applications of cap-and-trade considered in the text are included.

policy in the environmental domain. Its close relative, the independence property, has been particularly important in obtaining political support for the use of cap-and-trade systems to address environmental issues.

This property is of great relevance to the practical development of policy, because it allows equity and efficiency concerns to be separated. In particular, a government can set an overall cap of pollutant emissions (a pollution reduction goal) and leave it up to a legislature to construct a constituency in support of the program by allocating shares of the allowances to various interests, such as sectors and geographic regions, without affecting either the environmental performance of the system or its aggregate social costs.

Because of the importance of this property, we examined the conditions under which it is more or less likely to hold—both in theory and in practice. We find that in theory, a number of factors can lead to the independence property being violated. These are particular types of transaction costs in cap-and-trade markets; significant market power in the allowance market; uncertainty regarding the future price of allowances; conditional allowance allocations, such as output-based updating-allocation mechanisms; non-cost-minimizing behavior by firms; and specific kinds of regulatory treatment of participants in a cap-and-trade market.

Of course, that these factors can lead to the violation of the independence property does not mean that in practice they do so in quantitatively significant ways. Overall, we find modest support for the independence property in the seven cases we examine, although it would surely be useful to have more empirical research in this realm.

That the independence property appears to be broadly validated provides support for the efficacy of past political judgments regarding constituency building through legislatures' allowance allocations in cap-and-trade systems. Governments have repeatedly set the overall emissions cap and then left it up to the political process to allocate the available number of allowances among sources to build support for an initiative without reducing the system's environmental performance or driving up its cost. This success with environmental cap-and-trade systems should be contrasted with many other public policy proposals for which the normal course of events is that the political bargaining that is necessary to develop support reduces the effectiveness of the policy or drives up its overall cost.

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