TRADABLE CARBON ALLOWANCE AUCTIONS: HOW AND WHY TO AUCTION

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Cover photo: The main house at Airlie Center, the location of the Greenhouse Gas Emissions Trading Braintrust meetings. Photograph reproduced with the permission of Airlie Foundation.

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The Airlie Carbon Trading Papers

The Airlie Carbon Trading Papers are intended to help lay the intellectual foundation for a US greenhouse gas emissions trading system, which is a leading policy option for realizing cost-effective reductions of greenhouse gas emissions. The papers are the product of a unique research, analysis and dialogue process directed by the Center for Clean Air Policy. Since November 1996, the Center has convened regular meetings of its "Greenhouse Gas Emissions Trading Braintrust", a group of high-level representatives of industry, environmental organizations, state and federal government agencies and academe. The opinions expressed in these papers are those of the Center, though our views are informed by the extensive dialogue with Braintrust participants.

Braintrust members and Center staff conduct research and analysis of key design and implementation questions, then bring their findings and proposals to the group for discussion. The purpose of this process is to investigate alternative design options in detail rather than to arrive at consensus on a preferred option.

At the outset, the Braintrust identified a number of priority issues, including: definition of the instrument that would be traded, determination of who would be required to hold allowances, methods for allocating allowances, and the elements of the trading system compliance infrastructure. Braintrust members agreed to start with a focus on energy-related carbon dioxide emissions. Secondary issues identified by the Braintrust include the integration of additional greenhouse gases into the system, the incorporation of emissions reductions from forestry and land use activities and foreign countries, and the mitigation of any adverse impacts of carbon regulation on US industry.

Why the "Airlie" Carbon Trading Papers? The Airlie Center serves as the backdrop for the Braintrust's meetings. Situated outside the Washington, DC beltway in Warrenton, Virginia, Airlie provides an informal, congenial atmosphere that allows participants to leave their affiliations "at the door" and to build strong working relationships. These factors have been critical to the success of the Braintrust process.

About the Center for Clean Air Policy

Since its inception in 1985, the Center for Clean Air Policy has developed a strong record of designing and promoting market-based solutions to environmental problems. The Center's dialogue on acid rain in the 1980s identified many of the elements of the SO_2 control program that were adopted by the Bush Administration and eventually codified in the Clean Air Act Amendments of 1990. Since 1990, the Center has been active on the issue of global climate change. Center staff have participated in the Framework Convention on Climate Change negotiations and in domestic efforts to address greenhouse gases, analyzing and advocating market-based climate policies such as emissions trading and joint implementation. The Center brokered the world's first energy sector joint implementation project. The Center is also active in the areas of air quality regulation, electricity industry restructuring, and transportation and land use.

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Executive Summary

The US is now considering the establishment of a domestic greenhouse gas (GHG) cap-and-trade system as a means of achieving the emission reductions necessary to mitigate global climate change. A critical issue in designing the cap-and-trade system is the mechanism for allocating carbon allowances. Two methods have received most attention. One is auctioning the allowances, and the other is the allocation of allowances to regulated entities though the use of a formula based on historical output, energy use or emissions. The latter method is known as "grandfathering".

This paper argues that an auction is the best way to allocate allowances in a carbon cap-and-trade system. To minimize administrative costs, allowances would be required primarily at the level of oil refineries, natural gas pipelines, natural gas liquid sellers, and coal processing plants. To maximize liquidity in secondary markets, allowances would be fully tradable and bankable. The government would conduct quarterly auctions. A standard ascending-clock auction in which price is gradually raised until there is no excess demand would provide reliable price discovery. An auction is preferred to grandfathering (giving polluters allowances in proportion to past pollution), because it would allow reduced tax distortions, provide more flexibility in distribution of costs, provide greater incentives for innovation, and reduce the need for politically contentious arguments over the allocation of rents.

I. Introduction

Uncertainty still exists, but the mainstream scientific consensus, represented by the Intergovernmental Panel on Climate Change, believes that the balance of evidence suggests that there is a discernible human influence on global climate (IPCC, 1996). An international agreement to address the threat of global climate change is being developed with increasing urgency. At the same time, nations are beginning to analyze programs that could reduce their emissions of the greenhouse gases (GHGs) that contribute to global climate change.

One option for controlling emissions of GHGs is emissions trading. A cap-and-trade program establishes a cap on emissions and then distributes the allowable emissions (allowances) to regulated entities. This paper addresses a key question in designing a cap-and-trade system--how to distribute the allowances?

CO_2 is a uniformly mixed, accumulative pollutant. Neither the source of emissions nor their exact timing is important from an environmental standpoint.[1] Thus, allowances are ideally

[1] The timing of emissions does have an effect on subsequent trajectories of atmospheric concentrations, climate variables, and associated impacts. The significance of these changes is difficult to estimate. For this paper, we assume that only banking can occur—i.e., early emission reductions can free up allowances for later use. Thus, under no circumstances are emission reductions delayed.

defined in a homogeneous way over space and time. Ideally allowances would be fully tradable internationally. We do not deal with the difficult issues of international allowance trading system design such as monitoring and enforcement, but the conclusions of this paper on auctions are consistent with an optimal domestic system operating within an international trading system. For this paper, we assume that the allowance system would regulate carbon primarily at the level of oil refineries, natural gas pipelines, natural gas liquid sellers, and coal processing plants.[2] This would create a comprehensive, administratively feasible system. Carbon emissions in all sectors of the economy would be indirectly controlled. Allowances would provide the right to a one-time emission of one ton of carbon or carbon dioxide. They could be banked indefinitely for use in later years. Trade in the secondary allowance market would be completely unrestricted. None of this is contentious.

How then to allocate the allowances? One approach would be to "grandfather" allowances to emission sources based on historical rates. This approach would have the advantage of minimizing disruption to existing economic activity, because current emission sources would be guaranteed to receive the necessary allowances to continue production. (Of course, allowances would be reduced proportionately to achieve overall reduction goals.) There are, however, two significant disadvantages to grandfathering allowances. First, it would not achieve an efficient allocation of allowances. Second, it would require developing and administering complex and politically contentious allocation rules.

There is a simple and highly efficient alternative to grandfathering. Let the government sell the allowances in periodic auctions – just as the Treasury sells debt. Auctioning would result in a more efficient allocation of allowances, provide a stronger incentive for innovation, and reduce the need for politically contentious arguments over the allocation of rents. The bonus is that the revenue from the auctions could be used to offset distortionary taxes that reduce economic efficiency. This "revenue recycling" means that emitters effectively would be buying the right to emit from the public. If the target of stabilizing emissions at 1990 levels by 2010 were implemented, 1,340 million metric tons of allowances would be issued each year (EIA 1997 Annual Energy Outlook). Current estimates of the cost of carbon regulation suggest the marginal cost of this target would be in the range $25 to $150.[3] If the marginal cost, and hence the allowance price, were $100 per metric ton, an efficient auction could raise $134 billion annually. This is approximately ten percent of federal receipts and about two percent of gross national product (GNP) in 1995.

It is important to note that if allowances were given to energy companies, consumers would still pay higher energy prices. It is the carbon cap itself that would determine the price increase. Regardless of whether the government auctioned allowances or gave them away, the same energy price would be expected. The marginal cost of controlling carbon would not be altered

[2] The justification for this is discussed in "US Carbon Trading: Description of an Upstream Approach" by Tim Hargrave, Center for Clean Air Policy (1998). In brief, this point of regulation achieves near comprehensive coverage of carbon and minimizes the costs of administering the program. The paper also begins to outline the details of how carbon would be monitored in such a system. In principle, however, auctioning could be done in either an upstream or a downstream system.

[3] Gaskins and Weyant (1993), and Nordhaus (1991).

by grandfathering, only the initial ownership of carbon rights. The only difference would be distributional, with emitters either receiving or paying for emission allowances.

The experience in cellular communications provides a vivid illustration. In the 1980s, the FCC gave away cellular licenses. The companies did not respond with lower prices. Rather, prices were high, since only two companies could operate in each market. Now the FCC auctions licenses, generating billions of dollars for the Treasury. Prices are falling as these auction winners enter the markets of those who were given licenses.

This paper presents the issues in designing a carbon allowance auction. The analysis is relevant for achieving any aggregate emissions target. In previous work on environmental auction design, researchers considered the serious design problems in the SO_2 auction and its effects on the operation of the auction and market (Cason 1995; Cason and Plott 1996; Joskow, Schmalensee and Bailey 1997). The arguments for auctions have not been comprehensively addressed before, although many of the individual arguments have been discussed elsewhere. In particular, papers address the advantages of revenue recycling (Parry 1995), and the effects on incentives to innovate (Milliman and Prince 1989). In the context of the Acid Rain Program, Van Dyke (1991) argued that fairness required that SO_2 allowances be sold rather than given out for free. No previous work has addressed the full distributional implications of allocating carbon allowances through auctions rather than some form of grandfathering.

We begin by describing how carbon allowances should be auctioned. Then we consider the alternative, grandfathering, and argue why an auction is better. We conclude that bankable, identical allowances should be auctioned on a quarterly basis using a standard, ascending-clock design. In the case of carbon we conclude that the arguments for auctions rather than grandfathering on efficiency and distributional grounds are overwhelming.

II. How to Auction Carbon Allowances

An auction of carbon allowances answers two questions: who, on efficiency grounds, should get the allowances, and at what prices? The best answer to these questions depends on the government's goals. Presumably a primary goal is efficiency – to put the allowances to the best possible use. A secondary goal is revenue maximization. Indeed, a government concerned with efficiency must put some weight on revenue maximization, since revenues can be used to offset distortionary taxes. Fortunately, these goals are closely aligned. An efficient auction would raise substantial revenues.

A. What to auction

In any auction, it is crucial to define the items being auctioned. With carbon allowances this is a simple matter. Each allowance would represent one ton of carbon or carbon dioxide. To minimize regulatory transaction costs, allowances would be required of oil refineries, natural gas pipelines, natural gas liquid sellers and coal processing plants. Such an "upstream" system would be comprehensive and minimizes the number of parties that need allowances.

A basic fact from Treasury auctions is that the Treasury must pay for illiquidity. The less liquid the issue is, the greater the transaction cost. Illiquidity not only costs the seller money, but it also reduces auction efficiency. In the FCC spectrum auctions, the primary source of inefficiency stems from the exercise of market power in thin markets. Illiquidity increases the risk that some bidders may have market power in certain circumstances.

To increase liquidity in this market, all allowances would be the same after their date of issue, and allowances would be bankable; that is, an allowance issued for the year 2000 could be used in any later year. There would be no environmental loss in making allowances bankable. Current carbon emissions would be reduced to the extent that allowances were banked. Given the long life time of CO_2 in the atmosphere, short term voluntary banking is unlikely to have significant impacts on CO_2 concentrations. Allowing banking further increases liquidity in secondary markets, since all allowances are the same after their date of issue.

In addition, allowances could and should be auctioned not only for the current years but also for future issue years. Thus, some allowances for 2005 could be auctioned in 2000 even though they could not be used to offset carbon emissions until after January 1, 2005. Early auctions would facilitate the development of an active futures and options market, thus improving risk allocation.[4]

Market power should not be a concern in an auction for carbon allowances. Even in an upstream program, there would still be more than 1,700 allowance buyers. Most importantly, even the largest buyers would constitute just a tiny fraction of the market, as is seen in Table 1. This should be contrasted with the U.S. Treasury auctions where the top-five primary dealers routinely purchase over one-half of the issue. Despite this concentration, market power is not a serious problem in Treasury auctions.

It is inconceivable that any party would be successful in exercising substantial market power in the market for carbon allowances. Even the largest bidder (Peabody Holdings with 5.6 percent of the market) could gain little by understating demand. Attempts to corner the market to exclude competitors would be even more foolhardy. It would be impossible for a single firm to prevent competitors from buying allowances at auction or in an active secondary market for carbon allowances. None of the conditions that allow for market failure is present here.

Table 1 Carbon Allowance Needs across Firms - Direct Allowance Market Players

Carbon User	**Total Carbon produced in 1995 (million metric tons)**	**% of allowance market**
Oil Industry[5] (175 refineries)	**436**	**31.1 %**
Largest Oil Company (Chevron)	31.1	2.3%

[4] See Kerr and Toman (1998)
[5] U.S. Department of Energy, Energy Information Administration. (1996)

Second largest (Exxon)	28.7	2.0%
Largest 10 oil companies	226.7	16.2%
Coal Industry[6] (550 coal preparation plants)	**610**	**43.5 %**
Largest Coal Producer (Peabody Holdings)	79.3	5.6%
Largest 3 companies	158.6	11.2%
Natural Gas Industry[7] (150 natural gas pipeline companies and 725 natural gas processing plants)	**356**	**25.4%**
Total	**1402**	**100%**

B. Ways to auction many identical items

There is a great deal of experience in the auctioning of many identical items. In the most basic setting, a seller is offering a fixed supply of identical items. The buyers express their willingness to buy various quantities at various price levels by submitting bids at auction. An allowance auction fits the simplest case. The government desires to sell a fixed supply of identical allowances.

As in Treasury auctions, carbon allowance auctions should be held on a regular basis, perhaps quarterly. This would be frequent enough that firms would have a good idea of their likely needs. Quarterly auctions also would reduce the cash flow problems associated with less frequent sale.

We conclude that probably the best auction form is a standard ascending-clock auction, although any of the standard auctions for multiple units would work well. To show this we discuss the characteristics of the important auction options and their advantages and disadvantages. Many different auction forms are possible. They are best divided into two basic forms: sealed-bid auctions and ascending-bid auctions.

Sealed-bid auctions

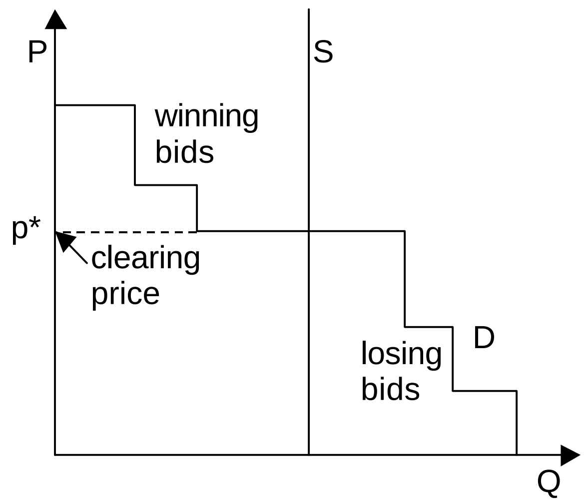
In sealed-bid auctions, the bidders simultaneously submit demand schedules. The auctioneer adds these demand schedules to form the aggregate demand curve. Typically, demand schedules are required to be step functions, but piecewise linear schedules are allowed in some settings. A sample demand curve appears in Figure 1. The point at which the aggregate demand curve and the supply curve cross determines the clearing price. All demands above this clearing price are filled, those at the clearing price are rationed, and those below are rejected. The various sealed-bid auction forms differ in what each bidder pays for the amounts awarded.

[6] U.S. Department of Energy, Energy Information Administration. (1997)
[7] U.S. Department of Energy, Energy Information Administration.

The two most common pricing methods are uniform pricing and pay-your-bid pricing. Under uniform pricing, each winner pays the clearing price p* for each allowance. With pay-your-bid pricing, each winner pays its bid. Of course, bidding behavior is quite different under the two approaches. With pay-your-bid pricing, the bidder attempts to guess where the clearing price is likely to fall and then bids slightly above it. Bids in excess of the clearing price are money left on the table. With uniform pricing, predicting the clearing price is less important, since every winner pays the clearing price regardless of how high it bids. With a uniform price however, bidders with market power may bid below their true value in an attempt to influence the market price. Neither pricing rule is fully efficient. In both, the bidders shade their bids in complex ways. This differential shading leads to inefficiency (Ausubel and Cramton 1996).

A third pricing rule, proposed by Vickrey (1961), does yield efficiency in a private value setting.[8] With Vickrey pricing, each winner pays the opportunity cost of its winnings; that is, the extra value that would be gained if its units went to the most deserving losers. Vickrey pricing eliminates all bid shading. It is a dominant strategy to bid your true demand curve. Vickrey accomplishes truthful revelation by rewarding large bidders for bidding their full demands. Each bidder pays less for additional units won.

Figure 1. Sample Demand Curve



Comparing the sealed-bid auctions is difficult, even in the setting with private values. Vickrey is best from an efficiency standpoint. All other comparisons are ambiguous. The distinction between uniform pricing and Vickrey pricing depends on the extent of market power. When no bidder has significant market power, then the outcomes are close, and uniform pricing is

[8] It is unclear whether a carbon auction is best thought of as a private value or a common value auction. In a private value auction, each bidder's value does not depend on information held by others, but depends on the bidder's particular situation. In a common value auction, all bidders have the same value for the good, and each has private information about this uncertain value. Common value auctions arise when the good is purchased for resale. A carbon auction would have elements of both.

nearly as efficient as Vickrey pricing. Uniform pricing has the added benefit that everyone pays the same price. Uniform pricing also encourages participation by small bidders, since it is strategically simple and the small bidders benefit from the demand reduction by the large bidders. In contrast, pay-your-bid pricing exposes small bidders to strategic risk, since they may be less able to gauge where the clearing price is apt to be. Hence, among the sealed-bid auctions, a uniform-price auction probably is best for the case of carbon usage allowances.

Ascending auctions

Ascending auctions have many advantages over sealed-bid formats. A reliable process of price discovery is a primary advantage. Both price and allocation are determined through a process of open competition. Each bidder has every opportunity to improve its bids, changing losing bids into winning bids. In the end, those willing to pay the most win the allowances. Bidders get to choose exactly how many allowances they want based on good information about price. An ascending process is especially desirable when bidders' valuations depend on information held by others. Then the bidding process reveals information, which improves the bidders' valuation estimates.

Multiple-unit ascending auctions can be conducted in two basic ways: with demand schedules or with an ascending clock.

The demand schedule approach can be thought of as a multiple-round version of the sealed-bid auctions. In each round, bidders submit a demand schedule. The schedules are aggregated to form the demand curve. The clearing price, where demand intersects supply, defines the tentative split between winning and losing bids. If this were the final round, those bids above the clearing price would be filled, those at the clearing price would be rationed, and those below the clearing price would be rejected. The process repeats until no bidder is willing to improve its bids.

To promote reliable price discovery an activity rule is needed. The activity rule prevents bidders from holding back initially and then submitting large bids after the other bidders have revealed their information. In most situations, the bidders will have (weakly) downward sloping demand curves. In this case, a simple yet powerful rule can be used without distorting behavior. The rule has three elements:

1. All bids must be entered in the initial round (that is, the total quantity that a bidder bids can only decrease).
2. Any losing bid that is not improved in the next round is permanently rejected.
3. The improvement must exceed the clearing price by at least the minimum bid increment.

This activity rule is the one-sided variant of a rule proposed by Wilson (1997) for the California Power Exchange's day-ahead electricity auction. The rule is based on the concept of revealed preference. Bidders are required to improve losing bids at the first opportunity. A failure to improve a losing bid is taken as presumptive evidence that the bidder's valuation is below the minimum bid (one increment above the prior clearing price). In this one-sided setting, prices only increase, so the unimproved bid can be permanently rejected.

The activity rule forces the bidders to bid in a way that is consistent with a downward sloping demand curve. A competitive process results in which winning bids get topped by losing bids. The process repeats until the clearing price reaches a point where a sufficient number of bidders find it sufficiently unattractive that excess demand falls to zero. At this point there is no further pressure to improve bids and the auction ends.

Either uniform pricing or pay-your-bid pricing can be used in the final iteration. In a sealed-bid design, the distinction between uniform and pay-your-bid pricing is large. In an ascending auction, the distinction is much less important, since winning bids under pay-your-bid pricing are apt to be close to the final clearing price in equilibrium. The reason is that a bidder has little incentive to raise the bid much more than one bid increment above the clearing price. Hence, pay-your-bid pricing shares the main advantage of uniform pricing.

Pay-your-bid pricing does have an important advantage over uniform pricing in an ascending auction. With uniform pricing, the bidders can submit bid schedules that create strong incentives for the other bidders to reduce demand. In particular, they can bid in such a way that the demand curve is quite steep above the clearing price. Faced with this steep curve, it is a best response for bidders to drop their losing bids, rather than continue to bid a large quantity, which would result in much higher prices. This is similar to the problem with uniform pricing in static auctions emphasized by Wilson (1979) and Back and Zender (1993), but here the problem is magnified, since the ascending process gives the bidders the opportunity to coordinate on a low-price equilibrium. For this reason, pay-your-bid pricing should be preferred in ascending auctions.

Ascending-clock auction

Better still is the ascending clock auction. The clock indicates the current price. In each round, the bidders submit the quantity they are willing to buy at that price. If the total quantity bid exceeds the quantity available the clock is increased. The bidding continues until the quantity bid is less than the quantity available. The allowances are then allocated at the prior price, and are rationed for those that reduced their quantity in the last round. The activity rule in this case is simply that each bidder cannot increase its quantity as prices rise.

This design shares all the advantages of an ascending pay-your-bid auction, and has several additional advantages:

1. It is easier to implement for both seller and buyers, since a buyer only bids a single quantity in each round, rather than a schedule.
2. There is no possibility of undesirable bid signaling, since only the total quantity bid is reported.
3. It avoids the mechanism for collusion under uniform pricing, yet yields a single market-clearing price.
4. Rapid convergence is guaranteed, since the price increases by one bid increment with each round of bidding.

A difficulty with all the ascending-bid approaches described above is that they are inefficient. In each case, bidders shade their bids in order to keep the price down. Large bidders tend to shade more than small bidders, since a particular price effect has a bigger impact on profits for a large bidder. This differential shading leads to an inefficient outcome. Large bidders win too little and small bidders win too much.

Ausubel (1997) proposes an alternative ascending clock auction that achieves efficiency. In the Ausubel auction, items are awarded when they are "clinched" and the price paid is the amount on the clock at the time of clinching. An item is clinched when it becomes mathematically impossible for the bidder not to win the item (that is, excess demand would fall to zero before the bidder could reduce its demand to zero). This pricing rule implements Vickrey pricing in an ascending format. Efficiency is restored without losing the advantages of an ascending-bid format.

However, in this setting where market power is apt to be slight, the inefficiencies from a standard ascending clock auction are likely to be insignificant. Hence, the equity and simplicity of having everyone pay the same price may be worth a modest inefficiency.
In years past, conducting an ascending auction for carbon allowances would have been difficult, because of the costs of getting all the bidders together at the same time and place. However, communication advances have now made it easy to implement an ascending auction of this scale over the Internet.

C. Desirable auction form for carbon allowances

We conclude that bankable and identical carbon allowances should be auctioned on a quarterly basis using a standard ascending-clock design. If it is viewed that an ascending auction is infeasible, then we prefer a sealed-bid uniform-price auction. Both the auction market and the secondary market should be open to all.

A carbon allowance auction would be the simplest of all multiple-unit auctions. The items auctioned would be identical and there would be an absence of market power. The banking of allowances would further increase the liquidity of the allowances. As such, there would be no impediments to creating a fully efficient carbon allowance auction. Indeed, auctions in much more complex and challenging settings have worked extremely well. Examples include the FCC spectrum auctions (Cramton 1997) and recent experiments with the day-ahead auction of electricity (Wilson 1997, Plott 1997).

Secondary markets for allowances likely would be highly efficient as well. These markets would complement an efficient auction, allowing firms to make adjustments to their allowance inventory on an as-needed basis.

III. Why auction rather than grandfathering?

Instead of auctioning, the government could give the allowances away to the regulated entities. This alternative is known as "grandfathering." The government could allocate allowances on the basis of past usage, on some measure of output, or based on more political considerations necessary to win support for enabling legislation. The traditional view is that grandfathering, while inefficient, is chosen because it provides greater political control over the distributional effects of regulation (Stavins 1997). We argue that auctioning is superior to any of these methods, because it allows reduced tax distortions, provides greater incentives for innovation, provides more flexibility in distribution of costs, and reduces the need for politically contentious arguments over the allocation of rents. We recognize that this does not mean auctions will be chosen. We argue however that these arguments may be more compelling in the case of carbon than they have been in SO_2 and other programs, and therefore may outweigh the political economy problems.

A. Efficient revenue raising

Auction revenue can replace distortionary taxes. Distortionary taxation creates a deadweight loss by inserting a wedge between marginal cost and price. Any efficient form of carbon regulation must make carbon scarce, thereby raising the marginal cost of using carbon. The rise in marginal cost implies a real cost of carbon regulation equivalent to the deadweight loss from distortionary taxation (see Figure 2). This real welfare cost corresponds to loss of output estimated to be on the order of 0.8 percent of GDP which would have been $60 billion in 1995 (Repetto and Austin 1997). At the same time, the regulation of carbon would create scarcity rents on the order of $134 billion. In a grandfathered system, these rents would go to those who received the allowances. In an auction system, the rents would be collected as revenue by the government. This revenue could be used to cut labor, payroll, capital, or consumption taxes or to reduce the deficit, all of which would create efficiency gains. Some could be used to further equity goals as discussed below.

Ballard, Shoven and Whalley (1985) estimate that each additional $1.00 of government revenue, raised through distortionary taxation, costs society $1.30. If we could gain revenue with no additional distortion, by auctioning rather than grandfathering, we could achieve significant efficiency gains. The revenue raised in the auction could be used to cut taxes and reduce the deficit. One concern commonly expressed by private sector actors is that government would not use the revenue well. While this may be true, with revenue of around $134 billion annually Congress would be forced to use the revenue in transparent and hence probably more socially beneficial ways. If the auction raised $134 billion annually, compensating tax cuts could increase GNP by up to $40 billion.

The "double dividend" argument is that not only are environmental goals achieved in a tax or tradable allowance system, but the tax system is also made more efficient through revenue recycling so that the overall cost of the policy is negative. Because of interactions with existing taxes, however, the carbon regulation could have higher costs than are immediately apparent (Bovenberg and Goulder 1996). For example, if the carbon regulation reduced the return to labor, it would exacerbate the existing distortion from the labor tax. These tax interactions would occur regardless of the form of regulation. Research strongly suggests that US carbon regulation would not generate a double dividend. The numbers above are consistent with this. Nevertheless, even if there is no double dividend from raising revenue through environmental regulation, it is always more efficient to auction. Parry, Williams, Burtraw and Goulder (1997) estimate that, if the emissions reductions are less than 23 percent, grandfathering allowances, and hence losing the value of revenue recycling, would double the cost of regulation relative to an auction system.

One criticism of the efficient revenue raising argument is that government spending is not exogenous. Raising revenue through auctions thus might not lead to equivalent tax cuts. Preliminary work by Becker and Mulligan (1997) suggests that more efficient tax systems are associated with larger governments. If this were the case, the efficiency gain from auction revenue would depend on the actual size of the tax cuts and what was done with the additional government spending.

B. Dynamic efficiency

The choice of auctions over grandfathering has dynamic advantages. Innovation reduces costs. This is always advantageous to firms. Innovation, however, also reduces scarcity rents. Industry incentives to innovate are even greater with auctions than grandfathering because, when allowances are auctioned, innovators benefit from the innovation-induced fall in allowance prices (Milliman and Prince 1989). In a grandfathered system these rents belong to the industry so there is no gain from reducing them.[9] Another dynamic advantage is that auctions guarantee liquidity and thus ensure the availability of allowances to new entrants and small traders.

Some people argue that firms are liquidity-constrained and that this limits innovation and adoption of new technology. This may be a reasonable argument for households buying new refrigerators, but is not reasonable for the likely recipients of grandfathered allowances such as large energy companies and manufacturers. A tax cut would more effectively provide resources to liquidity-constrained households and small firms.

C. Distributional effects of auctions

In studying the distributional effects we break them into two parts, the effects which arise through changes in prices and returns to factors, and the wealth effects of changing ownership of a resource. Ownership is being transferred from the commons to either the taxpayer, under auctions, or the recipients of grandfathered allowances. The price effects, which are the most complex effects, are the same regardless of the form of carbon regulation. In particular, they are unaffected by whether allowances are auctioned or grandfathered. The aggregate distributional effects depend on the sum of price and wealth effects.

[9] In fact the incentive to innovate depends not on whether allowances are auctioned or grandfathered, but on who owns the allowances at the time of innovation. If allowances are auctioned many years in advance, the incentives are identical under auctions and grandfathering. (Kerr and Toman, 1998)

Three aspects of the distribution of costs of carbon regulation are important because of concerns about equity, political feasibility or both. The extent to which "the polluter pays" is important for equity reasons, and from the point of view of environmental groups.[10] The way that costs are distributed across the income distribution, and the effects on particularly vulnerable groups, have clear equity impacts. The costs borne by specific interest groups are critical for political feasibility.

Theory of cost incidence

Three groups ultimately bear costs: consumers, workers and capital owners, especially current owners of physical capital. Consumers suffer loss of consumer surplus, workers suffer a fall in income, and capital owners suffer a fall in the value of their capital. Who bears costs does not depend on the legal form of the regulation, only on its effects on prices.

At every point in the economy, economic actors can pass changes in price due to carbon regulation forward to buyers, and backward to suppliers of factors of inputs.[11] When a domestic carbon allowance system is instituted, carbon becomes scarce and the cost (inclusive of the allowance) of domestic fuels containing carbon rises. If this rise in cost does not lead to an equivalent rise in wholesale price, the owners of the fuel sources lose.[12] The change in wholesale price depends on the relative elasticities of supply and derived demand. The elasticity of domestic supply depends partly on fossil fuel producers' access to international markets. The long run supply elasticity will be higher than the short run, because producers can alter exploration and development behavior. The elasticity of demand for fuel from producers depends partly on all the possible ways that downstream producers and consumers can reduce their use of specific fuels through fuel switching, increased fuel efficiency and changes in consumption. The cost incidence also depends on the industrial structure (Atkinson and Stiglitz 1980). In a monopoly, if supply is inelastic, producers will tend to bear the cost. If supply is elastic, the price rise will depend on the shape of the supply curve, the price could rise by more than the tax leading to a negative incidence on producers.[13]

In the same way that producers pass part of the cost forward with an increase in fuel prices, some can be passed backward through reductions in factor returns, to factors used in fossil fuel production, such as coal miners' labor. The effect on coal miners' wages depends on the elasticity of demand for coal miners, and their elasticity of labor supply to mining. In the short run at least, coal miners may be geographically and occupationally immobile, so may face significant wage reductions and unemployment.

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[10] In the case of carbon, "polluter pays" may be inappropriately judgmental in tone. However the logical replacement "user pays" has the same equity implications.

[11] Prices of substitutes and complements to factors, inputs and outputs will also be affected through cross elasticities. Some factors and consumers may benefit from rising returns or falling prices.

[12] As with a tax on land rent (Feldstein (1977)), not all the tax is borne by fossil fuel reserve owners even though in the short run they can do nothing to change their behavior.

[13] $MR = p(1-1/\eta^D)$ where η^D is the price elasticity of demand. With a constant elasticity demand curve, an d tax = τ, $MR = MC+\tau$ so $dp/d\tau = (1/(1-1/\eta^D)$ which is greater than one for a monopolist.

We can identify similar effects throughout the economy. As each producer faces a cost increase they pass some on to their demanders, as increased prices, and some back to their workers. In general, part of the cost increase can also be passed backward to owners of capital. If capital is specific to a particular industry, its supply is inelastic in the short run. The return to its use will fall, leading to a fall in its value. Coal fired electric utilities, gas pipelines, and industrial boilers are examples of immobile capital, which will fall in value. The current owners of these assets will face losses. Ultimately the price changes reach the final consumer of fossil fuel or any good produced using fossil fuel. How much of the cost consumers bear depends on the elasticity of demand for fuels and goods containing carbon, relative to the elasticity of supply. In the short run, consumer demand for fuel may be relatively inelastic, because they can only respond by reducing usage. In the longer run, they can invest in new heating systems, cars, houses, and appliances that allow them to switch fuels and increase energy efficiency.

Figure 2 Fossil Fuel Price and Quantity Effects from Carbon Regulation

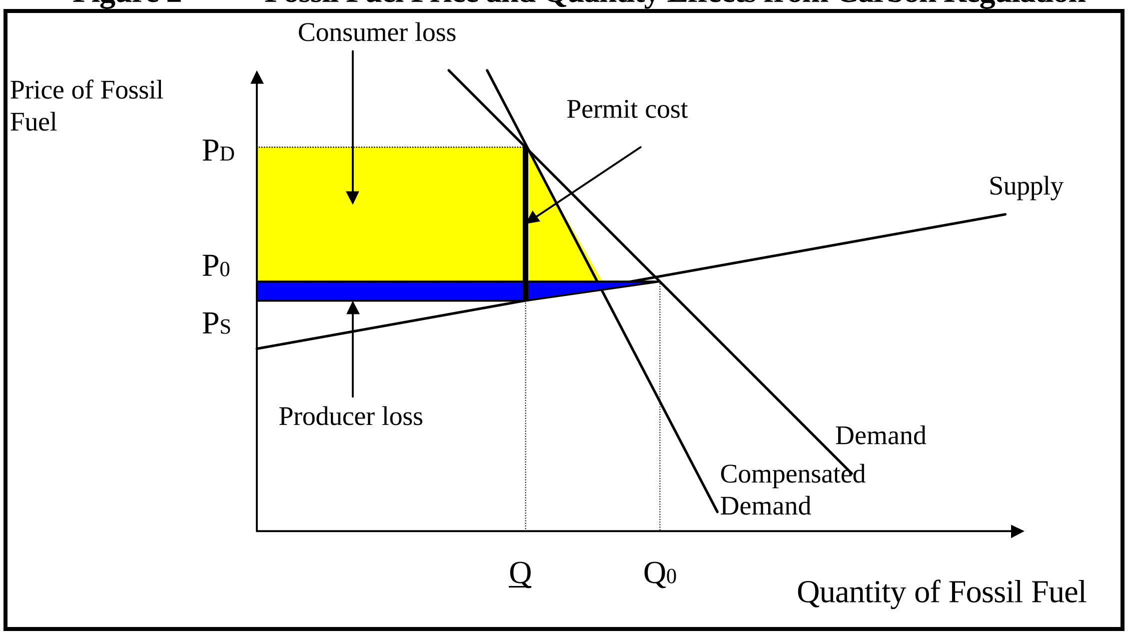

Figure 2 illustrates the losses to consumers and producers (passed on to factors). This figure assumes only one fossil fuel, and that it is sold directly from producers to the ultimate consumers. Q is the carbon cap translated into a fossil fuel cap. The figure shows how as the fossil fuel is restricted the price buyers pay rises to clear the market, and the price supply receives falls. The allowance price is the difference between these prices. In this illustration the buyer has inelastic demand and hence bears most of the price rise. The social cost is the sum of the loss of consumer and producer surplus. Consumer surplus is measured as the area under the compensated demand curve to reflect the amount consumers would be willing to pay to have the price lowered to its original level. We could draw similar figures for specific labor markets, specific intermediate product markets and physical capital markets.

In summary, the relative changes in prices (including wages and dividends) in response to the regulation, depend on relative elasticities of supply and demand for crude fossil fuels, specific types of capital and labor, and consumer goods. The overall cost to the economy of a given carbon target will fall with higher elasticities. The costs to specific individuals depend on these price changes, their ownership of different types of physical and human capital, and their consumption patterns.

Empirical evidence on the incidence of carbon regulation

A variety of empirical studies shed light on the incidence of carbon regulation. All current models assume that the tax is fully passed through to consumers. Thus they implicitly assume perfectly elastic supply of factors, or equivalently full factor mobility. Poterba (1990) considers the relative expenditure shares directly devoted to energy across the expenditure distribution. Casler and Rafiqui (1993) use a similar methodology for direct expenditures. They also use an input-output framework to estimate indirect incidence through the purchase of goods produced using energy. Dowlatabadi, Kopp and Tschang (1994) consider only direct effects but allow for partial equilibrium responses to energy prices. Jorgenson, Slesnick and Wilcoxen (1992) use a general equilibrium model to consider the lifetime incidence of carbon taxes through all possible channels.

The different models have several consistent qualitative results. All agree that the impact of the tax will be relatively, but not dramatically, regressive.[14] The indirect effects tend to reduce the regressivity. Consumer incidence varies significantly by region. The Midwest bears the highest costs; the Pacific states bear the lowest. Other results are less clear. Casler and Rafiqui find that rural households are harder hit, and the young less affected. Jorgenson et al. find the opposite. Jorgenson et al. find that large households are more affected.

None of these models can say anything about loss of capital income and therefore loss of capital value. To do this a model needs to identify the elasticity of capital in specific industries and the owners of capital. The models currently can say nothing about the effects of carbon regulation on labor markets. Also the models all assume perfectly competitive pricing, which may not be appropriate in some of the key industries.

The regional effects on employment and consumption may exacerbate each other to create short-run macroeconomic effects on local economies particularly in the East South Central region. The wide dispersion of owners and the high mobility of financial capital imply that the regional effects on capital value are unlikely to have local macroeconomic effects.

Identifying the cost distribution is a non-trivial exercise. It seems likely that costs will be slightly regressive across consumers, will reduce the income of shareholders in parts of the energy sector (especially coal producers and users), and will have impacts on immobile workers in the coal sector. Clearly more research is needed to clarify these relative effects on individuals.

[14] As Poterba (1990) points out, for consumers in the lowest expenditure quintiles who are receiving transfers, an automatic partial compensation mechanism exists through the indexation of transfers. This compensation is not captured in measures of regressivity.

Distributional effects under auctions and grandfathering

Prior to compensation, an auction system would distribute costs in the same way as a grandfathered system. Both systems would lead to a distribution of costs that was determined by general equilibrium cost incidence, factor endowments and consumption patterns. The underlying distribution would be broadly consistent with polluter pays. Those heavily dependent on fossil fuels for capital or wage income, or in their consumption patterns, would bear more costs. Groups that responded significantly and rapidly to the pressure to reduce fossil fuel use would be rewarded by lower shares of costs. The ultimate distribution of costs would vary between the options depending on how the auction revenue was used - who would benefit and how much efficiency was increased - and to whom the allowances were grandfathered.

The government could use auction revenue to reduce tax distortions and thus reduce costs throughout the economy. It could be used to reduce labor or consumption taxes, benefiting all taxpayers. Payroll taxes could be cut or personal exemptions increased, benefiting the poor and middle classes. The deficit could be reduced, providing benefits to current borrowers and future generations. Auction revenue could be used to directly compensate afflicted workers, and provide transition assistance to help them change industries or locations. It could be used to cut the capital gains tax and hence benefit capital owners. It could provide assistance to afflicted communities and regions during their transition to a less fossil fuel-dependent economy. Only the political process and the normal constraints on redistribution would limit the flexibility of compensation under auctions.

In contrast, grandfathering allowances would not yield efficiency benefits so total costs would be higher. It would redistribute wealth only to those who directly received allowances. If the government were to grant allowances to coal companies, electric utilities, and other large emitters, it would yield no benefits for workers in those industries, local economies or consumer prices. Grandfathering could compensate some current owners of specific capital if allowance allocations were carefully targeted. These owners, however, could be adequately and more efficiently compensated, if such compensation were thought necessary, through targeted tax breaks. It would be theoretically possible to grandfather the allowances to a wide range of workers, consumers and capital owners, but this would be a cumbersome way to achieve a less efficient result than a tax-cut auction.

Equity could be better achieved under auctions. Cost bearing would be widely spread, and, in the long run, all costs would be borne by consumers. Therefore compensation should also be more widely spread. Auctions could provide more flexibility than grandfathering in compensation. In addition, poorer people tend to be workers and consumers more than they are shareholders, so they would be unlikely to benefit from grandfathering. These arguments were also true for the Acid Rain program, where grandfathering was chosen, but as Joskow and Schmalensee (1997) point out, the effects were attenuated because the recipients of allowances were electric utilities subject to rate regulation. Utilities were expected to pass on the scarcity rents as lower electricity prices. In contrast, the energy sector does not generally face economic regulation, so prices would not reflect rents.

IV. The politics of auctions and grandfathering

A. Grandfathering

If allowances were grandfathered, interest groups would fight bitterly for a share of annual rents. This fight would lead to direct costs during the design of the policy. Groups would invest in lawyers, government lobbying, and public relations campaigns. Government officials would spend enormous amounts of time preparing and analyzing options and in negotiations. This would lead to high administrative costs and probably considerable delays in implementation. Problems of this nature in the allocation of the telecommunications spectrum ultimately led to industry support for the recent FCC auctions.

In addition, the enormous rents would mean that interest groups would continue to seek changes in the allocation over time. Firms might end up putting as much effort into rent capture as into finding efficient ways to reduce carbon usage. Investments might be delayed in the hope that high observed marginal costs would lead to more generous allowance allocations as compensation. The increased complexity of the program, which grandfathering would tend to create, might lead some groups to seek exemptions, or bonus allowances in particular circumstances. In the SO_2 case the negotiation process was costly and lengthy and the ultimate allocation formula reflects many special interests and exemptions (Joskow and Schmalensee 1997). Additional allowances were allocated to reward behavior such as investment in scrubbers.

B. Auctioning

In contrast, the main political economy problem with auctions is that potentially regulated entities would have a strong incentive to support grandfathering and oppose auctions in order to obtain a portion of the available rents. Because industry perspectives will be important in passing climate change regulations, these incentives could greatly influence the structure of the regulatory approach. This is particularly true because potentially regulated industries usually have much more concentrated interests than consumers, workers and indirectly affected sectors.

The only example of auctioned rights in the US is the recent spectrum auctions. In the spectrum auctions the politics may have been altered by the enormous cost to the industry from delays suffered while spectrum rights were fought over. Auctions also had efficiency advantages for the industry because of the extremely complex problem faced when allocating heterogeneous allowances with highly interdependent values. The design of the Spectrum Auction reflected this difficulty. In addition, in a fast growing industry, many powerful players were non-incumbents who were unlikely to receive grandfathered allowances. This may also be true in the electricity sector in the wake of deregulation.

In the case of carbon allowances, the energy industry is already beginning to lobby for some form of grandfathering. The more efficient and equitable outcome of auctions will only be achieved if it becomes clear how the true costs will be spread, and if other affected groups are mobilized to protect their interests. Carbon is different from previous environmental regulations because of its potential scale and the pervasiveness of energy use. The scale will make the distribution of rents more transparent. Powerful players in non-energy sectors may well find it worthwhile to engage in this debate.

Transparency, however, can also have a down side for auctions. The auction price would be publicly visible, and large amounts of money would be transferred between the private and public sectors. This would affect perceptions of the distribution of costs. It might hinder the passing of the carbon regulation as a whole. It would raise opposition from those who were skeptical that the program would be revenue neutral, with tax cuts completely offsetting the auction revenue.

V. Conclusion

We have addressed one key question concerning how best to design a carbon cap-and-trade program--how to distribute allowances? Scarce allowances could be allocated through auctions or grandfathering. It is in the interest of current emitters to argue for grandfathering – allocating allowances based on past energy use or emissions. Such a system would pass on all scarcity rents to the regulated entities. This would represent a huge windfall gain to these entities.

A much better approach would be for the government to auction allowances on a regular basis. An auction would get the allowances to those who most need them, complementing the secondary market. Most importantly, in an auction the government would keep the scarcity rents rather than private entities. Auction revenues could be applied to reduce distortionary taxes, thereby providing an efficiency benefit. The equity benefit would be that tax cuts would spread the scarcity rents broadly across society, more closely reflecting the distribution of costs.

Designing a carbon allowance auction would be especially simple. CO_2 is a uniformly mixed, accumulative pollutant. Neither the source nor timing of emissions is important. Hence, carbon allowances could be auctioned as a homogeneous and bankable good. Even in an upstream system, which minimizes administrative costs by requiring allowances where monitoring is easiest, market power would not be an issue. The largest firm now has only a 5.6 percent market share. Firms with less than a one percent share of the energy industry would hold the vast majority of allowances.

In this setting, we recommend a standard ascending-clock auction. The auction would begin at a low price. With each round, the bidders would be asked what quantity they demanded at the price posted on the auction clock. If there were excess demand, the price would be increased. This process would continue until the excess demand fell to zero. The bidders would then receive their quantity bid at the final price. This auction would generate a uniform price for carbon allowances. All bidders would get their demands at the market price. A secondary market would allow the sale and purchase of allowances as circumstances change. This design would assure a highly efficient allocation of the allowances.

We have proposed a tax-cut auction for carbon allowances. In the carbon case, the allowance design would be simple, and the costs are very high and dispersed throughout the economy. These factors make the design of an auction simple. Auctions are feasible and efficient. The normative case for auctioned carbon allowances is strong. Given that the forces of supply and demand, rather than who is legally liable to meet the regulation, determine costs, the government has neither an efficiency nor an equity reason to give scarcity rents to industry. The best way to control climate change is to minimize the costs and distribute the rents fairly with a tax-cut auction.

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