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Lok Sang Ho[1]

Abstract

This paper demonstrates that "grandfathering" of pollution rights may be inefficient when existing polluters enjoy market power or when there are increasing returns to abatement efforts. On the other hand an "auction and refund" approach, by effectively charging producers for the pollution they cause and refunding them in proportion to the value of their economic output levels, will result in greater efficiency and equity. Moreover, this will resolve the possible complaint that a revenue-raising auction constitutes a "taking" of private property, and will address the worry that emission rights auctions may lead to higher electricity prices. It is argued that thin trading of emission rights need not undermine the value of the emission rights auction.

1. Introduction

The idea of emission trading has had a long history, dating back to the mid 1970s, when the US Environmental Protection Agency experimented with the idea of requiring any increase in pollution from an existing or new source to be offset by emission reductions from other sources. Notwithstanding obvious theoretical advantages in

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such an arrangement, a recent study found such programs in the United States "have generally failed to generate considerable trades." "[R]etrospective reviews have tended to blame their shortcomings on high transaction costs, uncertainty and risk in obtaining government approvals, as well as lack of clear legal authority and clearly specified objectives." (Environmental Law Institute, 2001, [6]). The relative low volume of trades, however, does not in itself indicate that the marketization of pollution rights has "failed" as an instrument of public policy. As this paper argues, by auctioning pollution rights and refunding the revenue to polluters (after subtracting administrative and monitoring costs) in direct proportion to their output (economic output, not pollution) levels, the system will enhance efficiency and will generate huge economic benefits even in the absence of active trading among the polluters, because it allocates the pollution rights efficiently and encourages polluters to maximize the value of output per unit of pollution.

As pointed out by the EPA document (US Environmental Protection Agency, 2003, [11] p.2-6), in situations where greater environmental certainty is needed, cap and trade programs are preferable to emission charges or taxes because the cap sets an emission goal that pollution sources must meet. In principle, an annual emission cap can be set for a country, for a region, or even for the world as a whole.[2] The cap effectively generates a "quota" that can be distributed to existing or potential polluters within the region, the country, or the world, as the case may be. Nordhaus and Boyer [10] used the term "where efficiency" to refer to the efficient allocation of pollution over space—within a country, across a region, or over the globe, and the term "when efficiency" to refer to the efficient inter-temporal

[2] Asheim, et.al. (2006[1]) demonstrated that regional agreements often dominate global agreements for environmental preservation and may serve as a supplement, if not an alternative, for global ones.

allocation of pollution. Setting a cap on pollution over a defined space and adjusting it over time can potentially bring about both kinds of efficiency.

Traditionally it is believed that the initial allocation of the quota among polluters only has distributional consequences but not efficiency consequences. The distribution may be done administratively based on some stipulated criteria. Alternatively the distribution may be done through an auction mechanism. The political nature of the initial allocation is underscored by the fact that administrative distribution amounts to creating winners and losers (EPA, 2003, [11] p.3-14) by decree. On the other hand auctions, through treating all producers new and old as equals, are clearly fairer and more neutral, but they are regarded as a tax on the industry and so could constitute a case of "taking of private property."

As pointed out by the EPA document, distribution of the quota is always a difficult issue. Burtraw *et. al.* (2001, [3]) examined three alternative approaches to initial allocation. One is a revenue-raising auction. The second is "grandfathering," which would allocate allowances on the basis of historic generation. The third is a "generation performance standard," which would update allowance allocations based on shares of current electricity generation.[3] As expected, they found the auction to be "dramatically more cost-effective than the other approaches", but consumers would face the highest electricity charges. "The generation performance standard (GPS) leads to the lowest electricity price and consumers are best off under the generation performance standard when examining

[3] For example, as Beamon et.al. [3] explained: "if the national cap on CO_2 emissions were set at 1.914 billion tons (the 1990 CO_2 emission level for the electricity sector) and the total generation from all plants covered under the cap equaled 4 billion megawatthours in a particular year, the GPS would equal 0.479 tons CO_2 (0.119 metric tons carbon equivalent) per megawatthour generated."(p. 2)

just electricity price changes.” This result is clearly related to the fact that the revenue-raising auction represents a tax on the power generation industry. In contrast, “The allocation of allowances [under the generation performance standard] at zero cost represents a cost saving relative to AU (Auction) that is similar to GF (Grand Fathering). However, under GPS the allowances are allocated on the basis of generation, so firms are forced to compete for allowances by increasing generation at the margin. The subsidy implicit in the allowance allocation is netted against marginal cost, causing electricity prices and producer surplus to fall in competitive regions.” (p.22)

In this paper, I shall demonstrate that the auction approach does not have to involve revenue generation, as is assumed by Burtraw *et. al.* (2001 [3]). For the purpose of this paper and for simplicity I shall assume that polluters are all power companies. Their economic output is electricity. It is proposed that any funds raised through the auction net of administrative expenses be refunded to producers in the industry in proportion to the power generated. This approach will be seen as fairer, as favoritism cannot come into play. It will also end up reducing cost to consumers without compromising the effectiveness of the emission control.

In Section 2 I shall show that the assignment of pollution rights is not efficiency-neutral. I shall demonstrate that under the “grandfathering” of initial rights, even when open market trading of these rights in the subsequent periods is permitted, power generation is likely to be inefficient when the recipient enjoys monopoly power or when pollution abatement is subject to increasing returns the degree of which varies from producer to producer. Section 3 goes on to elaborate on a proposal of an auction combined with a refund policy and will demonstrate how it works. Section 4 will explain the rationale of the refund policy. Finally Section 5 will draw the conclusions.

2. Grand Fathering May be Inefficient

2.1 The Static Consideration

Traditionally, analysts think of emission rights trading as involving (1) allocating rights among existing polluters in the first place, and (2) setting up a mechanism to allow free trading of these rights thereafter. As mentioned above, Stage (1) is often presumed to entail only distributional consequences, so that regardless of how the pollution rights are distributed in the first instance, trading among polluters will see to it that the rights will go to whoever can utilize them most efficiently, thus resulting in efficiency.

This line of thinking is problematic for two reasons. First, the initial allocation of the pollution rights may prevent the potential polluters from enjoying and acquiring the economies of scale to compete. Those with the larger allocation are more likely to survive, even though they may not be efficient producers, while potential competitors may not be given any chance to compete at all. This has to do with dynamic efficiency. This point will be elaborated below.

Second is a static consideration that applies when the existing polluter wields monopoly power and is assigned pollution rights. Although in the absence of monopoly power a producer may be in his own self interest to sell these rights to others if the value is higher to others than to himself, if it wields monopoly power it may act like a profit-maximizing monopolist and may prefer to restrict the supply of pollution rights in an attempt to achieve the maximum revenue.

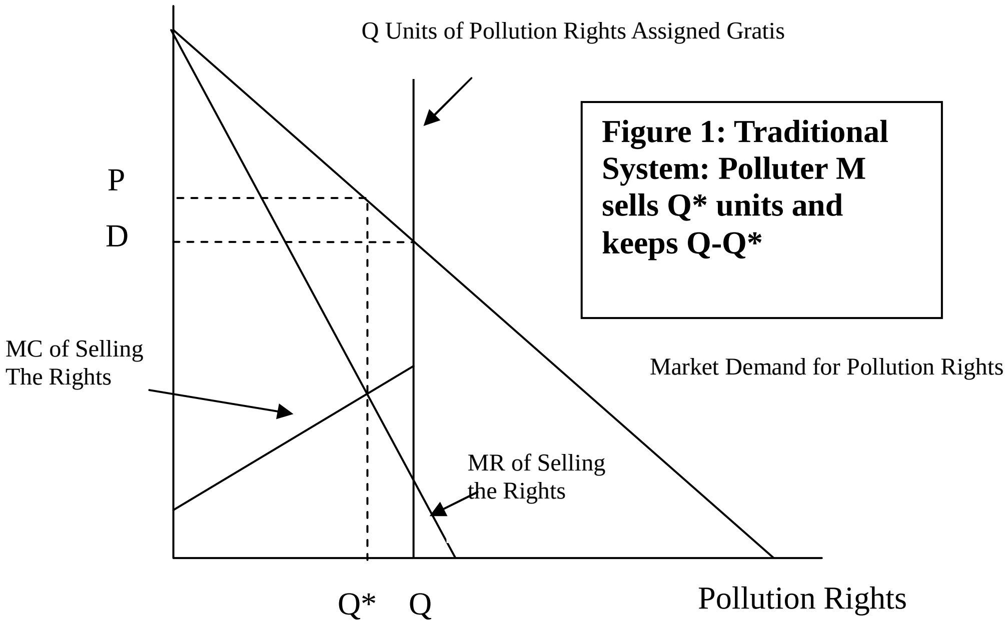

Figure 1: Traditional System: Polluter M sells Q* units and keeps Q-Q*

Note: MC is rising because as more is released to the market retained rights become fewer and more valuable. The opportunity cost of releasing the rights is the value of these rights to the original recipient.

In **Figure 1**, polluter M is assumed to be given free allocation of all the pollution rights. Suppose MC depicts the marginal cost of selling the pollution rights. The rising MC indicates that the more he gives up the rights the greater will be the opportunity cost, which is simply the value of using the rights himself. We have drawn MC as lying below D, which is the marginal social benefit of using the rights when all the quota is used up. Thus M is an inefficient polluter. MR=MC results in his profit maximizing sales Q*, with a profit maximizing price P, which his competitors have to pay. The polluter captures, in addition to PQ*, also the value under the MC curve from Q* to Q as it utilizes the retained quota Q-Q*.

In the example potential competitors are far more efficient but have no rights while the pre-existing polluter enjoys free rights. If the assigned rights are permanent, any improvement in productivity among new competitors, such as signaled by an upward shift in the demand curve (Market Demand for Pollution Rights), would further give the initial polluter a bigger capital gain as the pollution rights fetch a higher market price. This cannot be justified because it represents a growing economic rent arbitrarily distributed to the initial polluter, who does not have to improve its productivity at all, but captures much of the benefits of the productivity gains achieved by others.

2.2 The Dynamic Consideration

The dynamic consideration refers to the fact that pollution reducing technology may be subject to economies of scale or increasing returns, and that even if new competitors are potentially more efficient they will be cost-disadvantaged if existing firms enjoy free pollution rights while they have to purchase. We will assume that the price of pollution rights is not subject to the influence of any second-hand supplier. For example, the price of pollution rights may be determined in the regional or the world market.

Consider that a power plant has the following production function:

$$Q(K_Q, L_Q) \tag{1}$$

where K_Q and L_Q represent capital and labor devoted to power generation.

Environmental damage is assumed to be a function of output and abatement inputs:

$$D(Q, K_A, L_A) \tag{2}$$

where K_A and L_A represent respectively the capital and labor used in the abatement of the pollution. $D_1 > 0$, $D_2 < 0$, $D_3 < 0$. Increasing returns to abatement implies $D_{22} < 0$, $D_{33} < 0$

For power companies that enjoy a quota $\underline{D}$ which is the pollution entitlement for which no charge is applicable, his total profit function is:

$$P_Q\, Q(K_Q, L_Q, D) - P_K(K_Q + K_A) - P_L(L_Q + L_A) - P_D(D - \underline{D}) \qquad (3)$$

if D is bigger than $\underline{D}$.

In this case the power company j will need to buy additional pollution rights from the market, and their abatement spending offsets the cost of the pollution rights at the margin:

$$P_K = -P_D \frac{\partial D(Q, K_A, L_A)}{\partial K_A} \quad \text{, and}$$

$$P_L = -P_D \frac{\partial D(Q, K_A, L_A)}{\partial L_A} \qquad (4)$$

The profit function is equal to

$$P_Q\, Q(K_Q, L_Q, D) - P_K(K_Q + K_A) - P_L(L_Q + L_A) + P_D(\underline{D} - D) \qquad (5)$$

if D is smaller than $\underline{D}$

In this case the power company j will have pollution rights to sell to the market. Abatement allows the companies to spare rights that can be sold at a price. The first order marginal conditions (4) still apply and will not change. Total pollution from this power company $D^* = D^*(Q^*, K_A^*, L_A^*)$ where Q^*, K_A^*, L_A^* are all solved from the first order maximization conditions.

For power companies that do not enjoy any quota, the profit function is:

$$P_Q\, Q(K_Q, L_Q) - P_K(K_Q + K_A) - P_L(L_Q + L_A) - P_D D \qquad (6)$$

Now suppose a potential competitor i has a more efficient production function, so that pollution is smaller per unit of output, with the environmental damage function being:

$$D(aQ, K_A, L_A)\,, \qquad \text{where } a < 1 \text{ so that } \frac{\partial D_i}{\partial Q_i} = a\frac{\partial D_j}{\partial Q_j} \qquad (7)$$

Moreover, under increasing returns to abatement, $\frac{\partial^2 D}{\partial {K_A}^2} \langle 0$.

Although i could well replace j and would produce more output with the same pollution level, the "grandfathering" awards j with the free pollution quotas, rendering j profitable but i unprofitable. With the need to pay for all of its pollution i's marginal cost is higher and will fail to generate sufficient electricity for it to benefit from the economies of scale. The marginal cost of i can be obtained by differentiating:

$$P_K(K_Q+K_A) + P_L(L_Q+L_A) + P_D.D \qquad (8)$$

with respect to Q, which is equal to:

$$P_K\frac{\partial K_Q}{\partial Q} + P_L\frac{\partial L_Q}{\partial L} + P_K\frac{\partial K_A}{\partial D}\frac{\partial D}{\partial Q} + P_L\frac{\partial L_A}{\partial D}\frac{\partial D}{\partial Q} + P_D\frac{\partial D}{\partial Q} \qquad (9)$$

Although j's marginal cost would comprise similar terms, being the first derivative of the following expression with respect to Q:

$$P_K(K_Q+K_A) + P_L(L_Q+L_A) + P_D.(D-\underline{D}) \qquad \text{(10a) or}$$

$$P_K(K_Q+K_A) + P_L(L_Q+L_A) - P_D.(\underline{D}-D) \qquad \text{(10b)}$$

by virtue of the fact of increasing returns that it enjoys, one key component of the marginal cost, $P_D\frac{\partial D}{\partial Q}$, may be lower for j than for i.

Total cost (10a) or (10b) is also much lower than total cost for i, which is equation (8) for the same output, implying that average cost for j will be much lower than that for i.

3. The Proposal

Now consider the following proposal. Every year the government auctions an amount $\overline{D}$ and all polluters have to compete for these rights equally. All polluters, potential as well as existing, can compete for these rights in the open bidding process. The equilibrium price will make sure that $\sum D = \overline{D}$. Now it may be complained that some of the polluters, who had never been asked to pay any pollution tax or to buy any pollution right, are now asked to pay. The suddenly imposed cost may pose difficulties for them and they may not have the resources to address the problem. Ideally, the charges are recycled to support the investment to abate or to reward abatement already implemented. To address this complaint, I propose that the polluters be refunded the net revenues from running this system: i.e., after deducting any necessary administration or monitoring charges (=C), the amounts collected be all refunded, on a *pro rata* basis in proportion to the values of *outputs* (**Table 1**). Under this arrangement, those firms who have invested in reducing pollution and who enjoy a high "output value: pollution ratio", will collect an amount that may even exceed the amount paid to buy the pollution rights. On the other hand, firms that are inefficient, those who produce small output but large pollution, those who have never invested to reduce pollution, will be penalized the most. All firms will have the incentive to increase efficiency, and all investments, regardless of timing, that reduce pollution are rewarded as long as they are effective.

In principle the refunds should be based on the *values* of *approved outputs*. That would take care of situations in which different kinds of outputs are involved. It is possible that different kinds of outputs may be causing the same pollution that requires the specified rights. It will then not be possible to calculate the entitlements to refunds, if physical output units are used. Moreover, efficiency is in principle higher if polluters produce higher value outputs than if they produce lower value outputs, given the same pollution levels generated. However, there may be a potential problem if the prices of outputs are regulated prices rather than market prices, in which case imputed output prices may be more appropriate. The reason why the word "approved" is added is that we should not rule out the possibility that an original polluter is so successful that all pollution is eliminated. Approved outputs refer to outputs that are known to require a pollution-generating production process unless special investment is made to eliminate or to reduce the pollution. In the event that pollution becomes zero the original polluter may not need to buy any pollution rights at all. Yet he as a potential polluter should still be entitled to the refund as a reward for the pollution- eliminating investment that was made.

Table 1: Pollution Rights Bidding and Refund System

	Pollution Level	Output Level (in \$ of approved output)	Net Cost of Pollution Rights After Refund
Polluter 1	D_1	Q_1	$P_D D_1 - RQ_1$
Polluter 2	D_2	Q_2	$P_D D_2 - RQ_2$
Polluter 3	D_3	Q_3	$P_D D_3 - RQ_3$
Revenue collected/refunded	$P_D \sum D$ Collected	$R \sum Q$ Refunded	$P_D \sum D$ - $R \sum Q$

Notes: P_D is determined in the market through competitive bidding or auction of $\overline{D} = \sum D$ rights. R is the refund per unit of output determined by $(P_D \sum D - C) / \sum Q$ where C is the administrative and monitoring cost.

Within the year, any pollution rights that are found to have been purchased in excess can be resold in the open market. However, unused pollution rights at the end of the year will expire.[4] Thus no one will be able to capture the economic rent associated with the increasing scarcity value of the rights over time.

4. The Need to Plough Back Collected Revenue

The proposal to return all the revenue raised through the auction to the producers in proportion to the values of their outputs may be discomforting to those who look at the prices paid for the pollution rights as simply reflecting a cost that is inflicted on society. Ultimately, it is argued, the consumers of the products whose production involves some damage to the environment may need to pay for the cost of that damage. But prices are useful only as long as they guide resource allocation. If resource allocation is already optimal—and we are assuming that science has already established the optimal amount of pollution reduction and we are already implementing effectively the annual pollution quota—there will be no additional gains for raising prices higher than what is necessary for these purposes. In a world with two goods A and B and a single input, suppose optimal resource allocation is 1/3 of the resource for the production of A and 2/3 for the production of B. If production is efficient, and the resource allocation is optimal, then the equilibrium market prices consistent with this equilibrium must be optimal prices. The fact that the production of A causes pollution will not change the

[4] McKibbin and Wilcoxen (2002[8], 2003[9]) propose two kinds of pollution permits, one with an expiry date and one without in their “Blueprint”. The “Blueprint” is attractive in being flexible: the perpetual permits could be traded among firms, or bought and retired by environmental groups. Governments, too, could buy back permits in future years if new evidence on climate change indicates that emissions should be cut more sharply. But rents would accrue to parties that may not be seen as deserving.

fact that these are optimal prices—so long as the optimal resource allocation between A and B are in the ratio 1:2. A revenue-raising auction gives the government or the auction administration resources to be spent at their will. To the extent that this spending does not reflect the choices of individuals in the market place, this will lead to a deadweight loss.

The need to return any collected revenue to the industry is not only based on efficiency grounds but also on legal grounds. As Ellerman (1998 [5]) pointed out, auctioning the permits implicitly assumes that "the government owns the rights that are to be auctioned." Since "these incipient rights are possessed *de facto* by existing emitters and exercised by them" "the auction is not just a tax in disguise, but anticipatory confiscation of rights being established by time-hallowed use." (pp.2-4) Returning the revenue collected to the industry deals with this issue of the legitimacy of the implicit tax.

As was pointed out by Burtraw *et. al.* (2001[3], 2005[4]), under a revenue-raising auction the price of electricity generated will be higher than under revenue-neutral options, such as grandfathering or the generation performance standard. By itself, the fact that prices rise above what is necessary to bring pollution in line with what is considered optimal implies that efficiency is affected. In general, it will reduce profitability and reduce investment in power generation. But the pollution level is the same as under auction-with-plowback, less electricity will be generated at a higher price. Pollution per unit of power generated will actually be higher.

For simplicity let us assume that there are two industries X and Y. If there are no externality effects, optimal allocation of investment between the two industries is achieved when:

$$\frac{\partial PV_X}{\partial K_X} = \frac{\partial PV_Y}{\partial K_Y} \tag{11}$$

where PV represents the present value of the net income stream from each industry. If industry X produces an environmental damage, the present value of the cost of this damage should be netted out PV_X, so that

$$\frac{\partial (PV_X - PVC_X)}{\partial K_X} = \frac{\partial PV_Y}{\partial K_Y} \tag{12}$$

This condition would be achieved if external costs are fully priced. In that case any profit arising in a period would reflect the value of output minus all factor costs minus all pollution costs. As long as pollution is fully priced both output level and the choice of technology will be optimal.

An important question is exactly what fully pricing pollution mean? Since real prices are relative prices, the idea of fully pricing pollution is so that the technology of production is optimal and that the level of production of the outputs is optimal. As long as the socially optimal amount of emission rights are auctioned off and put into the most socially profitable use there is no need to further tax investment in power generation, which is what a revenue-raising auction amounts to. By plowing back the revenue to power companies in proportion to the power generated, we reward firms for choosing an efficient technology and avoid taxing them on top of requiring the emissions to fall back to the optimal level.

Effectively, under this system, the firm j's profit function becomes:

$$(P_Q + \frac{P_D \sum D - C}{\sum Q}) Q_j (K_{Qj}, L_{Qj}) - P_K (K_{Qj} + K_{Aj}) - P_L (L_{Qj} + L_{Aj}) - P_D D_j \tag{13}$$

The first order conditions for profit maximization are obtained by maximizing with respect to K_Q, L_Q, K_A, L_A. The existence of the refund motivates the firm to enhance its production efficiency.

$$\frac{\partial \Pi_j}{\partial K_{Qj}} = (P_Q + \frac{P_D \sum D - C}{\sum Q}) \frac{\partial Q_j}{\partial K_{Qj}} - P_k - P_D \frac{\partial D_j}{\partial Q_j} \frac{\partial Q_j}{\partial K_{Qj}} = 0$$

$$\Rightarrow P_K = (P_Q + \frac{P_D \sum D - C}{\sum Q}) \frac{\partial Q_j}{\partial K_{Qj}} - P_D \frac{\partial D_j}{\partial Q_j} \frac{\partial Q_j}{\partial K_{Qj}} \tag{14}$$

$$\frac{\partial \Pi_j}{\partial K_{Aj}} = -P_K - P_D \frac{\partial D_j}{\partial K_{Aj}} = 0$$

$$\Rightarrow P_K = -P_D \frac{\partial D_j}{\partial K_{Aj}} \tag{15}$$

In deriving these first order conditions, it is noted that since the total quota is fixed, one firm's increase in pollution will not increase the funds available for redistribution and will only affect how the total amount is shared. As a result all derivatives of $\frac{P_D \sum D - C}{\sum Q}$ with respect to K_{Qj}, L_{Qj}, K_{Aj}, and L_{Aj} vanish to zero. Moreover, since the first order conditions from differentiating with respect to L_{Qj} and L_{Aj} are direct mirrors of equations (14) and (15) they need not be repeated. From equation (14), we can see that the refund per unit of output increases the attractiveness of boosting production. Moreover, (14) tells us that capital should be utilized until the marginal social benefit of the capital is equal to the price of capital, and $\frac{P_D \sum D - C}{\sum Q}$ is as much part of the benefit of the marginal output as $P_D \frac{\partial D_j}{\partial Q_j}$ is an external cost when output-augmenting capital is put into production. In equation (15), capital for pollution abatement is utilized until the price of capital is equal to the savings from the reduction in the need for pollution rights.

There is a further point regarding the subtraction from auction proceeds before refund. While it was stated that auction proceeds minus administration and monitoring costs are refunded to power generation firms in proportion to the values of their outputs, "administrative and monitoring cost" is actually a variable that may affect outcomes. An emission rights market requires enforcement, and enforcement effort can be made bigger or smaller. Macho-Stadler and Perez-Castrillo (2006[7]) showed that the emission levels of firms will vary with the monitoring or auditing effort. Accordingly, as long as the marginal benefit in terms of this effectiveness is bigger than the marginal opportunity cost of the revenue, money should be deducted from the revenue raised to enhance the enforcement effort before the leftover is distributed.

5. Conclusions

The proposed system of openly auctioning yearly pollution rights assumes that we know how much pollution in total should be allowed. We may not have very accurate information on this, but any system of environmental management will have to either assume that we have the right target quantity of pollution (in which case the price of pollution rights is endogenous) or that we have the right price of pollution rights (in which case the amount of pollution resulting becomes endogenous). Once we have made this assumption, the proposed system will allow us to hit the target in the aggregate among the relevant jurisdictions and allocate the emission rights fairly and efficiently among existing and potential polluters. Pollution rights are not assigned according to historical pollution levels and have to be acquired on the same terms by all existing and potential polluters through an open auction. The collected revenues, after deducting administrative and monitoring costs[5], are recycled to provide incentives and financing for polluters to clean up and to improve efficiency. Because the “refund” is in proportion to the value of pollution-generating output firms that produce the greatest value for any given pollution are rewarded, while those that produce high pollution but little value are punished. Existing polluters will not be rewarded by large assignment of free pollution rights. Because pollution rights are defined over a specific time period most of the rights purchased through this competitive bidding process are expected to be utilized. Only the excess rights are resold and purchased by those firms that experience a shortfall. As a result only minimal emission trading is expected. Yet the system is efficient both because efficient firms are rewarded and because pollution rights are obtained by competition and not assigned by decree.

[5] These expenses can be paid in the first place from the general revenue and then paid back later on after the revenue from emission rights auction has been collected.

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