Rebating Environmental Policy Revenues: Output-Based Allocations and Tradable Performance Standards

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Abstract

Political pressure often exists to earmark environmental tax revenues or permit rents to the industry affected by the regulation. This paper analyzes schemes that rebate revenues based on output shares: tradable performance standards, an emissions tax with market-share rebates, and tradable permits with output-based allocation. All three policies effectively combine a tax on emissions with a subsidy to output. The result is a shifting of emissions control efforts toward greater emissions rate reduction and less output contraction, with higher marginal costs of control and lower output prices compared to the social optimum, given any targeted level of abatement. These welfare costs depend on the degree of output substitutability and are likely to be much larger in the long run. While some political and market-failure justifications may exist, policy makers should carefully consider industry characteristics before engaging in output-based rebating.

Key Words: emission tax, permit allocation, earmarking, tradable performance standards

JEL Classification Numbers: H21, H23, Q2

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Carolyn Fischer[0]

1 Introduction

Increasingly in recent years, countries in the Organization for Economic Cooperation and Development (OECD) have been incorporating economic instruments into environmental policy. While the United States has emphasized the use of marketable emissions permits, Europe, particularly Scandinavia, has begun to rely on emissions charges as a policy tool. Both types of policies have the potential for raising revenues while reducing environmental externalities. However, contrary to the literature on "double dividends," governments do not tend to use revenues from environmental policies to lower distortionary taxes.

Tremendous political pressure evidently exists to earmark environmental tax revenues to aid the industry affected by the regulation. The use of revenue earmarking to fund specific programs has been studied in some depth by political economists.[1] Traditionally, such public finance schemes tie an expenditure program to a specific tax policy, effectively treating the latter as a user fee for the revenue needs of the program.[2] However, recent policies aim to implement a tax policy for its incentive effects, while they tie the revenues to offset some of the burdens to the regulated parties. These self-contained, revenue-neutral environmental policies embed the earmarking directly into the environmental policy itself, using an allocation rule for rebating revenues back to program participants.

One rebating method that is frequently advanced is to allocate revenues according to output. However, since output is a control variable of the firm, the allocation policy itself has behavioral effects, which in turn

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[1]See, for example, Wagner (1991).

[2]Examples of these traditional earmarking schemes abound in the OECD: revenue from fertilizer charges in Austria and Finland help fund agricultural subsidies; France uses revenues from water pollution charges to fund discharge reduction and cleanup projects; and the United States (theoretically) earmarks gasoline taxes for highway improvements (OECD 1994c).

tends to reduce the efficiency of the environmental policy.

This paper focuses on three similar output-based allocation regimes: tradable performance standards, tax rebates, and emissions permit allocation. While these policies are not typically considered together, they are indeed similar forms of the same scheme: they each simultaneously impose a marginal cost to emissions and offer a subsidy to output. Furthermore, the marginal value of that subsidy is tied to the average value of inframarginal emissions to the affected industry.

While such output-based rebating policies do not yet abound, examples do exist, and they are gaining in popularity among environmental policymakers. An explicit program of tradable performance standards was implemented in the United States for the phasedown of lead. In 1982, the U.S. Environmental Protection Agency set an inter-refinery average for lead usage among importers and refineries producing leaded gasoline.[3] Refineries using less lead than the standard could sell these credits to others using more than average. Another less obvious example of tradable performance standards are the Corporate Average Fuel Economy (CAFE) standards for automobile producers. Since each manufacturer must meet a fleet average miles-per-gallon standard, this regulatory program is similar to an intra-firm tradable performance standard.

One tax-rebate scheme has recently received some attention in policy circles. In 1990, the Swedish government announced the implementation of an environmental charge on nitrogen oxide (NO_x) emissions beginning in 1992, Sweden's first tax based on actual emissions. The revenue is rebated to the affected plants in proportion to the amount of energy produced. The tax is intended to promote emissions reduction, while the rebate is intended to ameliorate the distributional impact of the tax since only large producers are affected.[4]

Similarly, output-based allocation has surfaced recently as a proposed rule for distributing emissions permits in a cap-and-trade system. In the United States, as tradable emissions permit systems are being discussed for a variety of pollutants, including carbon dioxide (CO_2) and NO_x, allocation regimes often rise in the policy debates to the level of importance of the regulatory constraints themselves. The type of policy

[3]This standard was 1.10 grams per leaded gallon (gplg). In 1985, permit banking was introduced as the standard was reduced to 0.50 gplg and ultimately 0.10 gplg in 1986. The trading program ended in 1988. (U.S. EPA 1997).

[4]The rate of 40 Swedish kroner per kilo (about $2.80/lb) was set to approximate the cost of reducing (and asserted to be the marginal damage of) NO_x emissions. The charge applies only to large combustion plants, since the measurement equipment is costly. Initially, the program applied to heat and power producers with a capacity of over 10 MW and production exceeding 50 GWh. The latter threshold was to be lowered to 40 GWh in 1995 and 25 GWh in 1997 (Swedish Ministry of the Environment and Natural Resources 1995). Only final energy producers are included, not industrial process burning. The original participating installations were responsible for about 6.5% of total Swedish NO_x emissions (OECD 1994c).

envisioned in this paper is one like that proposed by Lashof (1997) for a broad-based cap-and-trade system for CO_2. Each sector would be granted a fixed number of permits, and within each sector, individual firms would receive permits proportional to their share of their industry's output.

In the next section, we develop a simple model to compare the socially optimal environmental policy to tradable performance standards, the basic example of output-based earmarking. The implications of output-based distribution of environmental revenues are then discussed for the specific cases of taxes and permits. Section 3 discusses some of the reasons for output support and evaluates some of the output-based earmarking policies in practice. The final section concludes.

2 Model

This section presents the optimal allocation of output and emissions rates that a social planner would choose and compares them to the choices made by a firm facing an emissions policy with output-based revenue rebating. A simple, partial-equilibrium model is employed, using a representative firm. Some of the limitations of this approach will be discussed later, as other papers address issues of general equilibrium effects and of imperfect competition and cost heterogeneity. However, we choose to begin with the minimal model to capture the fundamental incentives of output-based rebating in a single, perfectly competitive industry.

The representative firm is assumed to be a price taker both in product and in emissions markets. Total emissions E are composed of the emissions rate μ times total output Q. Marginal costs of production $c(\cdot)$ are constant in output but a decreasing function of emissions rate: $c(\mu) > 0$, $c'(\mu) < 0$, $c''(\mu) > 0$. Environmental damages $G(\cdot)$, on the other hand, are an increasing, weakly convex function of total emisions: $G(E) > 0$ and $G'(E) > 0$ for $E > 0$; $G''(E) \geq 0$.

2.1 Optimal Policy

The social planner aims to maximize welfare, which is composed of consumer surplus net of production costs and environmental damages:

$$W = \int_{s=0}^{Q} P(s)ds - c(\mu)Q - G(\mu Q), \tag{1}$$

where $P(Q)$ is the inverse demand function.

If the planner were setting emissions rates directly, she would do so according to the following first-order condition:[5]

$$-c'(\mu^*) = G'(E^*), \tag{2}$$

where $E^* = \mu^* Q^*$.

The left hand side of this equation represents the marginal cost of reducing emissions via the emissions rate.[6] Thus, Equation (2) just restates the familiar finding that the marginal cost of emissions reduction should equal the marginal cost of the externality.

Meanwhile, the planner would set output levels such that the marginal benefits of another unit of output (the price), less the marginal production costs, just offset the marginal damage caused by the emissions that the additional unit of output would generate:

$$P(Q^*) - c(\mu^*) - G'(E^*)\mu_i^* = 0. \tag{3}$$

In other words, she wants the output price to equal marginal social cost, inclusive of the emissions cost embodied in that extra unit of output.

Economists since Pigou in 1938 have shown that pricing emissions, such as with a tax, can internalize the externality. A tax of $t^* = G'(E^*)$ in a decentralized equilibrium would produce the optimal allocation from the planning problem. All three policies in this paper create a marginal price for emissions. However, the addition of a subsidy has efficiency consequences.

2.2 Tradable Performance Standards

The basic case of output-based rebating can be effectively represented by tradable performance standards. With tradable performance standards, the average emissions rate is fixed by policy. To the extent a firm produces with emissions rates below the standard, that firm creates permits which it can sell; to the extent the firm produces with above-average emissions, it must purchase permits to cover the gap. The subse-

[5]This condition assumes that the marginal cost of reducing the emissions rate is not prohibitive at the no-policy emissions rate.

[6]Let $E = \mu q$. Then $\frac{\partial C(q,E/q)}{\partial E} = \frac{\partial C(q,E/q)/\partial\mu}{q}$.

quent equilibrium determines the price of emissions and total amount of emissions, such that the industry emissions rate average equals the performance standard.

This policy displays elements of both the tax-rebate and output-allocated permit schemes: As with permits, the effective emissions price is determined by the market. But as with taxes, the overall level of emissions is not fixed and varies with the market equilibrium.

Let τ represent the price of emissions permits under a tradable performance standard. The firm must buy permits to the extent it emits more than the standard, $\bar{\mu}$, which determines the industry's average emissions rate. In other words, the firm pays an emissions tax of $\tau\mu q$ and receives a subsidy equal to the average value of emissions embodied in its output, $\tau\bar{\mu}q$.

Consider our representative firm with constant marginal costs. Its profits now equal total revenues from the sale of output less the costs of production, less emissions costs net of the rebated subsidy:

$$\pi^S = (P - c(\mu) - \tau(\mu - \bar{\mu}))\, q. \tag{4}$$

Maximizing profits, the firm lowers its emissions rate until the marginal cost per unit of output equals the marginal price of emissions:

$$-c'(\mu) = \tau. \tag{5}$$

Furthermore, the equilibrium output price must equal marginal costs plus permit costs net of the subsidy:

$$P = c(\mu) + \tau(\mu - \bar{\mu}). \tag{6}$$

Note that while (5) resembles the planner's first-order condition for the emissions rate (2), the firm's marginal incentives for output (6) differ from those of the planner (3). For the same level of output, the firm's marginal profits with respect to output are higher by the amount of the average subsidy, $\tau\bar{\mu}$.

Let equilibrium values for the tradable performance standard regime be denoted by the superscript S. In a closed equilibrium, compliance with the performance standard implies $\mu^S = \bar{\mu}$; correspondingly, the permit price equals the marginal abatement cost at that standard: $\tau = -c'(\bar{\mu})$. Furthermore, the marginal permit price just equals the marginal subsidy per unit of output, so the equilibrium output price just equals marginal production costs, much as it would with no regulation. However, compliance with the performance standard raises marginal production costs compared to the no-regulation case (superscript 0); i.e., $P^S = c(\bar{\mu}) > c(\mu^0) = P^0$.

Total production in the market equilibrium is determined by consumer demand. The higher price resulting from the regulation corresponds to a lower level of output than in the absense of regulation; however, since the price does not include the marginal environmental cost of the emissions embodied in remaining production, output will be higher than in the socially optimal case.

Suppose the performance standard is set at the socially optimal rate, $\mu^S = \bar{\mu} = \mu^*$. Emissions rates and prices will then equal the Pigouvian rates ($\tau = t^*$). However, the equilibrium output price will be lower; thus, output will exceed Pigouvian levels ($Q^S > Q^*$). Consequently, emissions will also exceed optimal levels ($\mu^S Q^S > \mu^* Q^*$). In other words, *given any emissions rate, output-based rebating induces less total emissions reduction.*

Figure 1: Efficiency Loss with Tradable Performance Standards

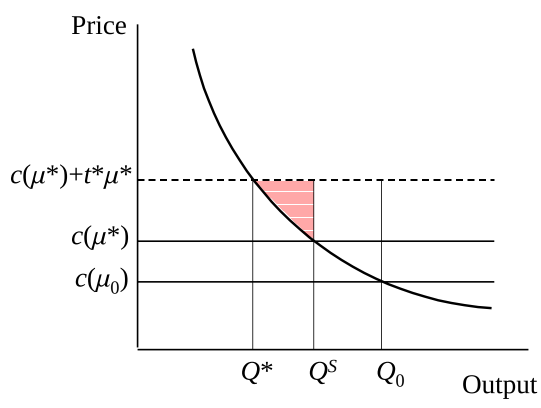


Figure 1 portrays the excess burden of tradable performance standards compared to optimal emissions pricing. This area equals the environmental damages from excess production ($\tau\mu^*(Q^S - Q^*)$), less the corresponding consumer surplus.

While the main characteristics of tradable performance standards—e.g., the output subsidy and the higher marginal cost of emissions control—are common to all output-based rebating schemes, the particular policies do have specific differences. Obviously, each one fixes a different policy variable: average rate of emissions, the price of emissions, or the total amount of emissions. Consequently, the equilibrium effects of the policies may differ. Relaxing the assumption of perfect competition can cause the individual firm incentives under the different programs to vary as well, but this case is not considered here.[7]

2.3 Output-Rebated Emissions Taxes

This policy combines an emissions tax with an output-based allocation of the revenues to achieve a revenue-neutral environmental policy, much like the Swedish NO_x program. Formally, let t represent the tax on emissions. Total tax revenue is rebated back to firms according to their share of industry output; the resulting subsidy equals the average value of emissions embodied in a unit of output. For firm i in an industry of n firms,

$$\sum_{j=1}^{n} t\mu_j q_j \frac{q_i}{\sum_{j=1}^{n} q_j} = t\bar{\mu}^T q_i, \tag{7}$$

where

$$\bar{\mu}^T \equiv \frac{\sum_{j=1}^{n} \mu_j q_j}{\sum_{j=1}^{n} q_j}. \tag{8}$$

Under perfect competition, firms do not believe they can affect the average emissions rate of the industry; it follows that the marginal output subsidy implied by the rebate equals the average per-unit subsidy.[8] Thus, for our representative firm, the tax-rebate scheme looks just like the tradable performance standard:

$$\pi^T = \left(P - c(\mu) - t(\mu - \bar{\mu}^T)\right) q. \tag{10}$$

The difference is that the marginal price of emissions is now fixed while average industry emissions (the performance standard) is endogenous.

The first-order conditions for profit maximization thus look the same as under standards. The marginal cost of emissions reduction equals the marginal price of emissions ($-c'(\mu) = t$). Meanwhile, the equilib-

[7] Fischer (2000a) examines the case when a firm's market shares among program participants are significant, either due to imperfect competition or imperfect participation.

[8] The assumption of perfect competition for the purposes of this paper implies negligible market share, i.e. $q_i/Q \approx 0$, where Q denotes industry output. Therefore, the competitive firm does not individually affect the industry average emissions rate:

$$\frac{\partial \bar{\mu}^T q_i}{\partial q_i} = \bar{\mu}^T + \mu_i \frac{q_i}{Q} - \bar{\mu}^T \frac{q_i}{Q} = \bar{\mu}^T. \tag{9}$$

See Fischer (2001) for the analysis with significant market share.

rium output price equals marginal costs plus permit costs net of the subsidy, or $P = c(\mu) + t(\mu - \bar{\mu}^T)$.

In equilibrium (denoted here by superscript T), we see that for the same simple constant-cost case with Pigouvian emissions pricing (setting $t = t^*$), the tax-rebate scheme functions just like the tradable permit scheme. The first-order condition for the emissions rate $-c'(\mu^T) = t^*$ implies $\mu^T = \mu^*$, and the marginal subsidy cancels the marginal tax on output: $P^T = c(\mu^*)$.[9]

2.4 Output-Allocated Permits

As just seen, with rebated emissions taxes and tradable performance standards, optimal emissions rates and prices lead to greater than optimal emissions. The dual to this problem is that to achieve the same level of emissions as the optimal case, the regulator must then take into account the greater output and tighten the performance standard. Correspondingly, the marginal price of emissions must rise. Thus, *for a given amount of emissions reduction, output-based rebating raises the marginal cost of emissions reduction* relative to efficient policy.

To illustrate this result, consider the case of output-allocated emissions permits. Let γ represent the price of an emissions permit. Permits totalling $\bar{E}$ are allocated among program participants according to output shares. The rebate to individual firm i thus equals

$$\bar{E}\frac{q_i}{\sum_{j=1}^{n} q_j} = \bar{e}q_i, \tag{11}$$

where $\bar{e} \equiv \bar{E}/Q^P$.

As in the preceding section, the assumption of perfect competition implies that the individual firm does not perceive an impact on the industry average allocation of its own production behavior. Thus, we can simply write profits for our representative firm as revenues less production costs less the value of net permit purchases:

$$\pi = (P - c(\mu) - \gamma(\mu - \bar{e}))\, q. \tag{12}$$

As with the other policies, the firm equalizes the marginal cost of emissions rate reduction with the marginal price of emissions: $-c'(\mu) = \gamma$. And the equilibrium output price equals marginal costs plus

[9] However, if entry or significant market shares among participants were present in the model, this equivalence would be lost.

permit costs net of the subsidy:

$$P = c(\mu) + \gamma(\mu - \bar{e}). \tag{13}$$

However, the equilibrium prices and subsidy will differ from the preceding two scenarios, as both are endogenous now. Furthermore, they will vary according to the industry's place in the overall permit market structure. The important distinction is that the subsidy is not a function of the industry average emission rate but rather the average allocation.

Restricted Permit Market

Let us define the restricted permit market as one where all the firms participating in the permit market compete in a single allocation pool. Let us also assume that firms remain price-takers. Total emissions for the restricted market are fixed at the Pigouvian level of overall emissions.

In this case, the average permit allocation equals average emissions in the self-contained permit program, and $\bar{e}^P = \bar{\mu}^P$. Given that $Q^P > Q^*$ due to the presence of the output subsidy, to achieve the required emissions level, average emissions rates will have to be lower: $\bar{\mu}^P < \mu^*$. As a result, permit prices will be higher, reflecting the higher marginal cost of control: $\gamma^P = -c'(\mu^P) > -c'(\mu^*)$.

Figure 2: Efficiency Loss with Output-Allocated Permits

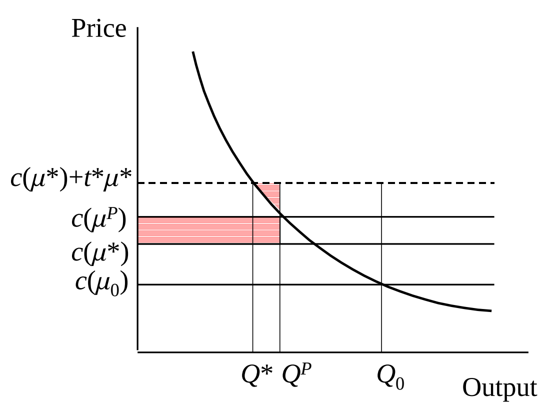


Figure 2 shows the excess burden of output-allocated permits compared to the social optimum. The dead-weight loss occurs in two parts: (i) higher-than-optimal production costs ($(c(\mu^P) - c(\mu^*))Q^P$), and (ii) the damages implied by emissions from the excess production, less the corresponding consumer surplus.

In other words, even though total emissions are at their optimal level, the marginal damages from output still exceed the marginal benefits.[10]

Broad-Based Permit Market

Now suppose permits are traded across a market that is much broader than the group of firms in the particular allocation pool. For example, a particular sector with output-based allocations could compete in a multisectoral market for greenhouse gas permits. To consider the industry-level effects, let us assume for now that the broad market is otherwise efficient and $\gamma^B = t^*$.

In the simple case with constant marginal costs, optimal emissions pricing implies that emissions rates under the broad scheme equal the optimal rate, or $\mu^B = \mu^*$. However, the per-unit allocation, $\bar{e}$, no longer equals industry average emission rate. Suppose policy makers choose $\bar{E} = \mu^* Q^*$ to reflect optimal emissions for that industry. Because of the presence of a subsidy, $Q^B > Q^*$ and, correspondingly, $E^B > E^*$. However, this implies that the average allocation rate is less than the average emission rate: $\bar{e}^B = \mu^* Q^* / Q^B < \mu^*$. This result in turn means the implicit average subsidy ($t^* \bar{E}/Q^B$) is less than with the comparable tradable performance standard. The smaller output subsidy then implies higher output prices and lower equilibrium output than with tradable performance standards, or $Q^B < Q^S$. Correspondingly, equilibrium emissions will also be lower (although still greater than optimal), as $E^B < E^S$.

2.5 Comparison

Table 1 summarizes the results from this section and compares the effects of the different rebating policies. In summary, output-based rebating shifts emissions reduction efforts toward emissions rate reduction and away from output substitution. This higher marginal cost of control is reflected in a higher permit price (or higher tax) and lower performance standard for any given amount of emissions reduction.

The combination of the preceding points implies an equilibrium departing from social efficiency, with too much production and too much effort toward reducing emissions rates. Compared to the absence of any

[10]This picture actually slightly underrepresents this loss. It assumes in effect that there is no difference in the social marginal cost in the two equilibria, i.e. $\tau^* \mu^* + c(\mu^*) - \tau^* \mu^P - c(\mu^P) = 0$. Using a Taylor series expansion, this difference can be approximated by $-\frac{1}{2} c''(\mu^*)(\mu^P - \mu^*)^2 < 0$. In other words, in the distorted equilibrium, the social marginal cost is somewhat higher than in the optimal equilibrium, according to the convexity in the abatement cost function.

Table 1: Comparison of Earmarking Schemes: Policy Effects

Policy	μ	P	E
Optimal Policy	μ^*	$c(\mu^*) + t^*\mu^*$	E^*
Tradable Performance Standards	$\mu^S = \mu^*$	$c(\mu^*)$	$E^S > E^*$
Tax-Rebate	$\mu^T = \mu^*$	$c(\mu^*)$	$E^T = E^S > E^*$
Output-Allocated Permits: Restricted	$\mu^P \leq \mu^*$	$c(\mu^P)$	$E^P = E^*$
Output-Allocated Permits: Broad	$\mu^B = \mu^*$	$c(\mu^*) + t^*\mu^*\left(1 - \frac{Q^*}{Q^B}\right)$	$E^S > E^B > E^*$

regulation, of course, output will still be lower. Correspondingly, the equilibrium output price will be higher than in the no-regulation case but lower than in the fixed-distribution case. Thus, output-based rebating mitigates the rise in the equilibrium output price due to regulation.

Although we have used the emissions rates and taxes from the optimal scenario as the basis of comparison for the rebating scenarios, it is important to note that they are not optimal when one imposes the constraint of rebating. Choosing a tradable performance standard is a second-best welfare maximization problem, as output essentially becomes a function of the standard in the decentralized market equilibrium. In the modified planner's problem, the first-order condition with respect to output is not satisfied, so in choosing the emissions rate, the planner also must take into account the impact on output:

$$-c'(\mu)Q - QG'(E) + \frac{dQ}{d\mu}(P - c(\mu) - \mu G'(E)) = 0. \tag{14}$$

Using $P(Q) = c(\mu)$ and simplifying,

$$-c'(\mu^{2nd}) = G'(E^{2nd})\left(1 + \frac{dQ}{d\mu}\frac{\mu}{Q}\right). \tag{15}$$

Thus, the second-best performance standard will tend to be higher according to the elasticity of output with respect to the emissions rate. That elasticity is positive and depends on the demand and cost functions.[11] The intuition is that, with a performance standard rather than a direct price to emissions, emissions embodied in output escape taxation. The standard must then do extra work to reduce emissions, both directly by reducing the emissions rate further and indirectly by raising costs and reducing output.

2.6 Multi-Sector Permit Markets

Since many pollutants are emitted from a variety of activities and rarely just a single sector, it is worth devoting some attention to the issue of multiple sectors and output-based rebating. Performance standards are almost invariably specific to the activity being performed. Conceivable policies of tradable performance standards or tax-rebate schemes for multiple sectors would always have the average emission rate in each sector equal to its standard (or average allocation). As just presented, each sector would emit more than they would with the Pigouvian tax alone, and sectors with greater elasticities of demand will over-emit to a greater extent. A combined cap-and-trade program, besides fixing overall emissions, raises some different issues since the cross-sector trade in permits breaks the link between average emission rates and average allocations.[12]

An actual output-based emission permit program is likely to display elements of each of the permit

[11] A caveat is the partial-equilibrium nature of this model. Bernard, Fischer and Vielle (2001) perform second-best analysis in a general equilibrium framework. They find that the optimal tax (and thereby emissions rate) when 100% rebating is imposed may be higher or lower, depending on the elasticity of substitution between goods, the emissions rate of the other sector, and whether or not the other polluting sector can be regulated.

[12] The question of what happens under a single cap-and-trade program is similar to the question of how to set standards or taxes for each sector in order to achieve an overall emissions target. However, it is not identical, since a permit system restricts the per-unit marginal cost of emission rate reduction to be equal across sectors.

scenarios presented in section 2.4. Consider a broad-based market in which each sector allocates its own pool of permits according to output shares.[13] By the same logic as the restricted market model, equilibrium permit prices in the broad market must be higher than optimal, since output subsidies require more emission rate reduction and higher marginal costs of emissions control. If the sectors are not identical—that is, if they display different cost structures, emissions, or demand elasticities—the implicit subsidies and their effects will vary. Then, as in the broad-based market example, the average allocation will not necessarily reflect average emissions in each sector, and each will tend to over- or undershoot their optimal emissions targets.

To understand the intuition behind this result, consider this simple but extreme example: two sectors compete in a single permit market, each with output-based allocation of permits within the sector, but one sector has perfectly inelastic demand.

Let Sector 1 be that sector; its total allocation equals $\mu_1^* Q_1^*$, and since the equilibrium output level does not change, its average allocation always equals μ_1^*. It then has an output price of

$$P_1 = c(\mu_1^M) + \gamma^M(\mu^M - \mu_1^*). \tag{16}$$

Meanwhile, Sector 2 faces more elastic demand. It receives a total allocation of $\mu_2^* Q_2^*$, which will correspond to an average allocation of $\mu_2^* Q_2^* / Q_2^M$. The price in that sector then equals

$$P_2 = c(\mu_2^M) + \gamma^M(\mu^M - \mu_2^* Q_2^* / Q_2^M). \tag{17}$$

In a permit market equilibrium, we know that total emissions across sectors must equal the total cap:

$$\mu_1^M Q_1^* + \mu_2^M Q_2^M = \mu_1^* Q_1^* + \mu_2^* Q_2^*, \tag{18}$$

and that marginal costs of reducing emission rates per unit of output must be equalized at the permit price:

$$-c'(\mu_1^M) = -c'(\mu_2^M) = \gamma^M. \tag{19}$$

[13] The term "sector" is used, but the analysis applies to any group of firms sorted into a single allocation pool. The assumption of perfect competition requires that their output not have a perfect substitute with producers in another allocation pool, as any difference in the effective subsidy would wipe out a group.

Start at the point of socially optimal emission rates and production. Any price can correspond to the optimal quantity in Sector 1, but in Sector 2, at a price of $P_2 = c(\mu_2^*) < c(\mu_2^*) + t^*\mu^*$, a greater quantity will be demanded: $Q_2^M > Q_2^*$. The emissions embodied in the extra output would violate the cap, so permit prices must rise and emission rates fall in both industries: $\gamma^M > t^*$, $\mu_1^M < \mu_1^*$ and $\mu_2^M < \mu_2^*$. Maintaining the cap, Sector 1 will then emit less than the socially optimal amount, while Sector 2 will emit more.

Compare this equilibrium to separate restricted permit markets. Permit prices in a market restricted to Sector 1 would reflect optimal control costs; permit prices in Sector 2 would reflect much higher-than-optimal control costs. The broad-based permit price would then fall in between, with Sector 1 lowering emission rates and Sector 2 raising them (but still not above the optimal rate), so that $\mu_2^P < \mu_2^M < \mu_2^*$.

For Sector 2, lower permit costs and control costs mean consumer prices are even lower than in the restricted permit market case.[14] Consumer prices in Sector 1 must also be lower; according to the first-order condition for profit maximization, if a firm wants to decrease its emission rate below $\mu_1^P = \mu_1^*$, it must be that $c(\mu_1^M) + \gamma^M(\mu_1^M - \mu_1^*) < c(\mu_1^*)$. Essentially, higher permit prices raise the value of the subsidy which depresses consumer prices.

Figure 3 shows the product market equilibrium in each sector when the same output-based allocation is used in permit markets restricted to each sector compared to a broad market allowing permit trades between sectors. The shaded areas represent efficiency losses compared to the social optimum. The patterned areas represent transfers. With separate permit markets, consumers in the sector with inelastic demand reap the full benefit of the output subsidy, but efficiency is not affected.[15] In Sector 2, the efficiency losses described in section 2.4 apply. When these sectors are then allowed to trade permits, Sector 1 reduces its emission rate and is more than compensated by the subsidy transfer. Sector 2 raises its emission rate and buys permits, finding that cheaper than abating on its own.

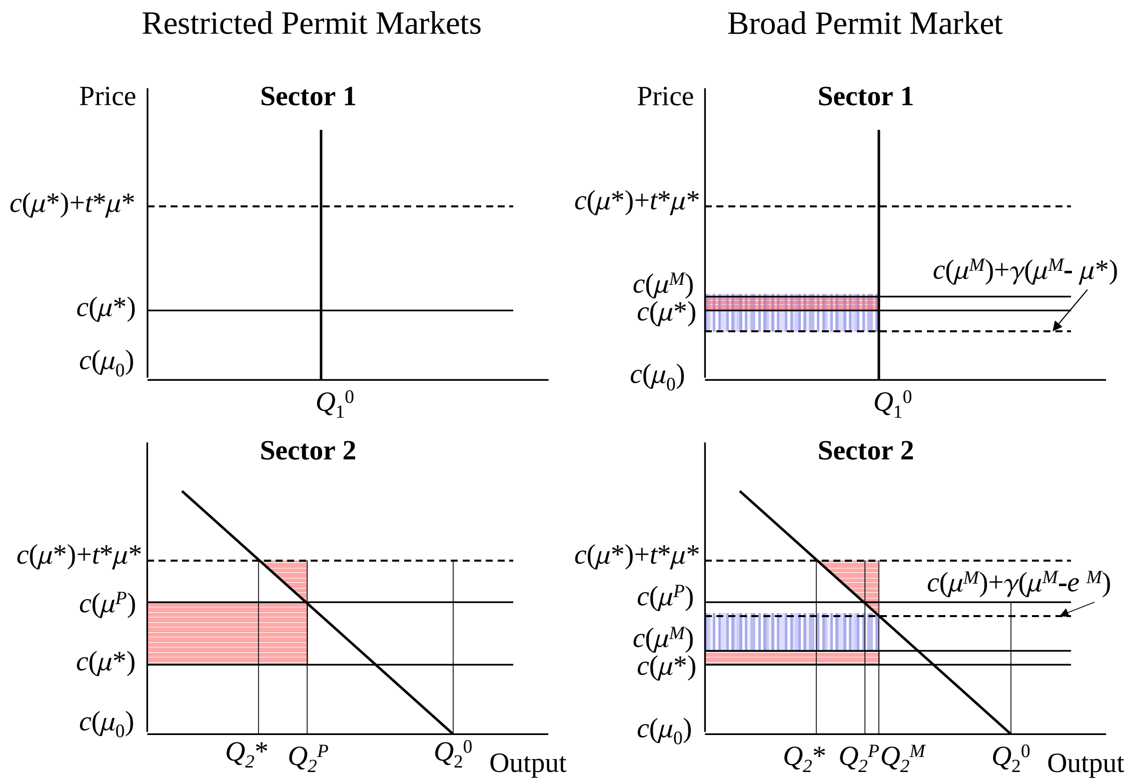
[14] The proof is shown by the contrary: suppose $P_2^M > P_2^P$ and $Q_2^M < Q_2^P$. Then $\bar{e}^M > \bar{e}^P t$, which means

$$\begin{aligned} P_2^M &= c(\mu_2^M) + \gamma^M(\mu_2^M - \bar{e}^M) \\ &< c(\mu_2^P) + \gamma^M(\mu_2^P - \bar{e}^M) \\ &< c(\mu_2^P) + \gamma^M(\mu_2^P - \bar{e}^P) \\ &= C(\mu_2^P) = P_2^P, \end{aligned}$$

which violates the original premise. The second step follows from the first-order condition for profit maximization with respect to the emission rate. Thus, it must be that $P_2^M < P_2^P$.

[15] Without the possibility of output substitution, the subsidy becomes like a lump-sum payment, equivalent in welfare terms to raising the revenue in an auction and redistributing it back in a lump sum, although the particular recipients might not be the same.

Figure 3: Efficiency Loss with Sector-Specific Output-Allocated Permits



Taken from another view, *output-based allocations create false gains from trade*. The result is that trade lowers prices for output in both sectors compared to separate permit markets. Recall the current assumption that each sector gets allocated exactly the permits it would need, so under an optimal policy (or lump-sum allocation) no net trade between sectors would be necessary. Restricted permit markets with output-based allocation raise marginal abatement costs according to how much output substitution would normally occur, creating abatement cost differentials across sectors according to the elasticities of demand in those sectors. Thus, in a multi-sector permit market with output-based allocations, sectors with relatively inelastic demand functions realize a comparative advantage in abatement arising, in a sense, from their greater ability to pass costs along to consumers.

But what about total welfare compared to restricted permit markets? (We know by definition the multi-sector market with output-based allocation must be suboptimal in the absense of other market distortions.) Overcompliance in Sector 1 represents a real resource cost. Sector 2 does reduce its overcompliance with respect to emission rate reductions, which saves some formerly wasted resources, but its output price reflects even less of the cost of the embodied emissions. As the costs of reducing emission rates are presumably convex, cost savings will arise from spreading overcompliance across the sectors. Thus, the question is whether those savings outweigh the additional efficiency loss from more overproduction in Sector 2. A general equilibrium model is then needed to estimate the resulting sectoral shifts in compliance burdens and the impact on overall costs of emission regulations.[16] These techniques become even more useful in gauging the equilibrium welfare effects when other market imperfections are present, as will be discussed in the next section.

3 Support for Output

Environmental policy, of course, does not operate in a vacuum. The efficiency of a standard Pigouvian tax or an equivalent emissions permit system relies on the assumption that markets are not otherwise distorted. Where distortions exist, environmental policy may exacerbate them, rendering simple Pigouvian policies suboptimal. Four major examples come to mind: (i) imperfect competition, (ii) imperfect participation, (iii) tax interaction, and (iv) innovation externalities. However, in no case is output-based rebating likely to be the best response.

For an imperfectly competitive industry that already underprovides output, an environmental policy with an output subsidy could raise welfare. In essence, two problems exist: insufficient output due to imperfect competition and overproduction of emissions due to the externality. Thus, two policy tools are needed to address them both, one to internalize the externality and one to encourage output.

A similar problem exists when the environmental program exempts significant portions of an industry (for example, if small producers do not need to participate). Since they bear no environmental burden, excluded producers suddenly have relatively low costs compared to participants. Industry production will then tend to shift away from participants toward non-participants (who are still emitting costlessly). An output subsidy for participants would discourage such intra-industry shifting of production and emissions.

However, in both these cases an output subsidy tied one-to-one to revenues is invariably not the optimal

[16] This general equilibrium analysis is performed in Bernard, Fischer, and Vielle (2000).

one and could be worse than no subsidy at all. First of all, it is tied to the value of inframarginal emissions, not to the degree of output underprovision or to the environmental impact of output shifting. Bernard, Fischer and Vielle (2001) assess the optimal tax and subsidy rates in several second-best settings when one sector of polluters are difficult to regulate or tax. They find that when an emissions tax cannot be imposed on one sector, the next best policy is to tax that sector's output and not rebate anything to the regulated sector. If an output tax is not possible either for the unregulated sector, then rebating is only warranted in cases where the goods are close substitutes.

Second of all, if the industry is imperfectly competitive (or program participation restricted), market shares will certainly be non-negligible, making the marginal subsidy endogenous to the output decision. Fischer (2001) addresses these issues. Different effective tax and subsidy rates result if firms are heterogeneous, and output (and emissions rate reduction) can be shifted inefficiently toward high-cost firms. As a consequence, overall costs—and perhaps overall emissions—would rise. Additional distortions arise if firms are not price takers. In general, therefore, where output support for program participants is warranted, that policy is best decoupled from the environmental policy.

The third example is the distortion of labor markets by income taxation. Taxing labor income distorts the labor-leisure tradeoff; in a sense, it taxes all consumption goods at the same rate, making them more expensive and making consuming leisure more attractive relative to consuming goods. Adding an environmental policy that makes some consumption goods even more expensive further distorts this tradeoff.

Environmental policies that raise revenues that can be used to lower distorting labor taxes unambiguously raise welfare from the no-policy scenario. However, the optimal environmental tax (or auctioned permit price) in this second-best setting is still less than the Pigouvian tax.[17] Policies that do not raise revenue (like grandfathered permits) must have positive environmental benefits that outweigh the increased deadweight loss from the labor tax on the margin.[18]

By providing a subsidy to output, output-based rebating may mitigate some of the impact of the tax interaction effect compared to lump-sum redistribution. The implicit subsidy lowers the price of the dirty good, making goods consumption in general less expensive and real wages higher. However, the gain from

[17] This result is well established in the literature: Bovenberg and van der Ploeg (1994); Bovenberg and de Mooij (1994); Fullerton (1996); Bovenberg and Goulder (1996); Parry (1995).

[18] See Parry (1996); Parry, Williams and Goulder (1996); Goulder, Parry, Williams and Burtraw (1997).

a reduced disincentive must be balanced against the higher abatement cost of achieving the same level of emissions reduction. The net result may (or may not) be an improvement over distributed permits in this situation.[19] Bernard, Fischer and Vielle (2000) evaluate a system of CO_2 permit trading in a general equilibrium framework, where each sector allocates its permits based on output shares. They find that the rules for determining initial sectoral allocations are important: Sectoral distributions based on value added generate effective subsidies more like a broad-based tax reduction and outperform lump-sum allocations. Distributions based on other rules like historic emissions create different and more distorting subsidies and underperform grandfathering. Still, in all cases output-based rebating is strictly less efficient than regular emissions taxes or auctioned permits. These policies raise revenues that offset labor taxes and encourage more work, and they achieve this in a manner that does not distort the relative prices of dirty and clean goods.

Finally, externalities in the provision of R&D can affect the optimal choice and stringency of environmental policy.[20] Proponents of output-based rebating view the subsidy as an added incentive for innovation. However, in the absense of the rebates, output prices would be higher and provide that extra incentive. To the extent output-based rebating raises compliance costs, it does then raise some incentives for innovation. But to the extent any innovation for lowering emissions rates is widespread enough, it will not only lower tax (or permit) costs, but also lower rebate values. The latter effect tends to diminish incentives for innovation relative to efficient policy.[21] Innovation is also impacted on the demand side: for example, if energy prices do not rise as much, less demand exists for developing energy-saving technologies. Thus, output-based rebating is not likely to provide as strong incentives for innovation as efficient, market-based environmental policies.

[19] Goulder et al (1998) show that performance standards can generate fewer efficiency costs than distributed permits in this second-best system. In their model, performance standards are less costly the less abatement is to be done by output adjustment than by emissions rate adjustment. On the other hand, Jensen and Rasmussen (1998), using a general equilibrium model of the Danish economy, find that allocating emissions permits according to output dampens sectoral adjustment but imposes greater welfare costs than grandfathered permits.

[20] See Fischer, Parry, and Pizer (1998).

[21] See Fischer (1999).

4 Unexpected Entry and Exit

A final caveat regards the issue of entry and exit from the regulatory program. In comparing policies designed to influence emissions behavior, a well-known distinction between a tax and a subsidy is that firms that may be unprofitable under the former may be profitable with the latter (Bramhall and Mills, 1966; Baumol and Oates, 1988). Output-based rebating schemes effectively combine taxes and subsidies; as a result, the problem of entry remains and becomes even more complicated. If program eligibility can be affected by firm behavior, an opening for rent-seeking is created.

Output-based rebating policies raise issues of not only for long-run incentives to enter and exit the industry, but also of short-run behavior like the altering of products or production to gain (in)eligibility. This section concentrates on the latter problem. The costs of short-run rent seeking are likely to dominate those from inefficient long-run exit incentives for incumbants, particularly for limited-duration programs (like the lead phasedown).

Exit is a common problem for regulatory programs. While exit can reflect firm unprofitability in the long run under socially efficient prices, activities to gain exemption generally reflect economic inefficiencies. In the case of these programs, firms with high emissions rates (μ_H) will be willing to engage in nonproductive activities to become ineligible for program participation. They will pay up to $\tau(\mu_H - \bar{\mu})$ per unit of output (assuming negligible market share) to remain outside the program. These nonproductive costs can manifest themselves in the form of foregone profits. The Swedish program shows some evidence of this type of exit activity. The initial cut-off for participation was boiler production of 50 GWh; several plants were subsequently noted to maintain boilers with a production of 48-49 Gwh.[22]

Entry, on the other hand, is a problem endemic to subsidies. Since all of these programs effectively offer a subsidy to output, incentives to gain eligibility exist as long as the potential subsidy outweighs the tax or permit cost. In other words, excluded firms with below-average emissions (μ_L) will be willing to pay a per-unit price of k up to $\tau(\bar{\mu} - \mu_L)$ to join the program and get a share of the permit rents or tax rebates.

The lead phasedown is a prime example of the unexpected entry problem. Producers suddenly had the incentive to take unleaded gasoline and add small amounts of lead to make the product eligible for creating permits. Small, hard-to-regulate intermediaries came onto the scene, blending leaded gasoline with fuel

[22] *The Swedish Experience*, p. 46.

alcohol to dilute lead content and generate permit credits. Thus, a new industry of blenders was born purely out of this regulation.[23]

Not only do such non-productive activities represent direct welfare losses, but they can also affect the market equilibrium of the rebated environmental policy. As firms enter, not only are rents shifted from incumbents to entrants, but the marginal subsidies and permit prices are also affected. With free entry, firms will continue to pay to join the output-based rebating program until average emissions and/or the equilibrium permit price adjust to equalize the rents to the costs of eligibility (i.e., until $\tau(\bar{\mu} - \mu_L) = k$). The impact of entry on the effectiveness and efficiency of the output-based rebating system ultimately depends on which policy variable is fixed.

With tradable performance standards, average emissions are set. As low emitters enter (and high emitters exit the program), the average baseline emissions rate falls, loosening the constraint on average emissions and causing the price of permits to fall. As a result, less abatement is performed, due to the permit price drop and exit. At the same time, the output subsidy falls as well; initial participants will then receive less support, while entrants receive unintended output support.

With output-based rebating in a tax regime or a broad-based permit system, the price of emissions is fixed at the tax rate. As low emitters enter (and as high emitters exit), the average program emissions rate falls, in this way lowering the output subsidy. Support is dissipated to the entrants; meanwhile emissions price incentives for the remaining incumbents become more efficient.[24]

In the case of a self-contained system of emissions permits allocated according to output, total participant emissions are capped. As low emitters enter, average emissions fall, lowering the marginal subsidy at any permit price; incumbents then overcontrol to a lesser extent, tending to bring down the marginal cost of control. Meanwhile, because total baseline emissions rise (unless entrants are non-emitters), the constraint binds more, which tends to raise equilibrium permit prices. The combined effect on permit prices is unclear. On the other hand, the effect is clear for exit: as high emitters exit, average emissions fall and the constraint loosens concurrently. This reaction tends to drive down both permit prices and output subsidies.

[23] By the end of 1985 about 600 alcohol blenders were participating, overwhelming the administrative infrastructure designed for fewer than 200 refineries (EPA, 1997; Kerr and Maré, 1996). Furthermore, while fuel alcohol can raise octane when blended with gasoline, this method is not as cost-effective as using methyl tertiary butyl ether (MBTE), derived from methanol produced from natural gas (GAO, 1997).

[24] If market shares within the program are an issue, entry also causes market shares to fall, thus tending to eliminate discrepancies between different effective tax rates.

For intuition, it is useful to examine the extreme case, where non-emitters can enter costlessly and high emitters cannot exit. In other words, let $k = 0$ and $\mu_L = 0$. In the context of the model in earlier sections, we should note that we have considered the incumbent industry as having constant marginal costs, making the number of firms irrelevant. To keep the following thought experiment simple, let us maintain this assumption and assume that, while other firms may enter the emissions program, they do not actually enter the same product markets. In other words, while the entrants' output may be eligible for emission credits, it is not a substitute for the incumbents' output (in fact, it may even be generated purely for rent-seeking purposes). We therefore will focus on the share of entrants in the emissions market, rather than on number of firms. Furthermore, that share will affect the product market equilibrium of the incumbents, but only through the emissions market. Let ρ represent the fraction of program participants composed of these entering non-emitters.

Table 2: Comparison of Earmarking Schemes: Entry

Policy:	μ	P	$\rho \to 1$
Tradable Performance Standards	$\mu^S = \frac{\mu^*}{1-\rho}$	$c(\frac{\mu^*}{1-\rho}) + \tau(\mu^S - \bar{\mu})$	$E^S \to E^0$
Tax-Rebate	$\mu^T = \mu^*$	$c(\mu^*) + t^*\mu^*\rho$	$E^T \to E^*$
Output-Allocated Permits: Restricted	$\mu^P \leq \mu^*$	$c(\mu^P) + \gamma\mu^P\rho$	$E^P \to E^*$
Output-Allocated Permits: Broad	$\mu^B = \mu^*$	$c(\mu^*) + t^*\mu^*\left(1 - (1-\rho)\frac{Q^*}{Q^B}\right)$	$E^B \to E^*$

Table 2 summarizes the effects on emissions rates, prices, and total emissions as the program share of entrants grows approaches 1. In the limit of all the cases, average baseline emissions are driven to zero. The tradable performance standard is thus met without any behavioral modification (or reduction in emissions), and the price of those permits is driven to zero as well. On the other hand, the tax-rebate case returns to the standard Pigouvian tax for the initial participants, with revenues disbursed among the entrants as the marginal subsidy is driven to zero. The same occurs with the broad-based permit system. In the self-contained cap-and-trade system, since entrants do not add to overall emissions, the emissions constraint remains the same; however, the marginal subsidy is driven to zero. The program then becomes like an auctioned permit program to the incumbents, and permit prices fall to their efficient levels. (Of course, if entrants do not have zero emissions, and permits are not traded outside the participants in the allocation program, entry causes the cap to bind more tightly, raising compliance costs of the incumbents as well as dissipating their subsidies.)

Thus, opportunities to manipulate eligibility tend to undo the redistributive goal of output-based rebating. And in the case of performance standards, entry tends to undo the goal of emissions reduction itself. With the other policies, such entry can push price incentives back toward efficient levels, but this comes at another efficiency cost if nonproductive resources are expended to gain eligibility.

5 Conclusion

The intent of rebating environmental policy revenues is to mitigate the cost burden on participants; the reasons may be equity, the prevention of production shifting to unregulated sectors, or plainly for political support of the regulation. Output-based rebating is attracting attention because it provides a seemingly fair rule of distribution of the policy rents and because it allows the allocations to respond to changes in market conditions over time.

However, output-based rebating sacrifices some of the efficiencies of market-based environmental policies. Allocating by market share essentially provides a subsidy to output, which creates a bias away from conservation and toward emissions rate reduction. The result is a higher marginal cost of control, a lower equilibrium output price, and a greater cost when achieving any given level of emissions reduction, compared to an efficient policy. The size of the welfare loss from this distortion depends on how much emissions would normally be reduced through output substitution.

The desirability of output-based rebating as a dynamic allocation mechanism is compromised by the fact that the accompanying distortions grow larger in the long run. Elasticities of substitution in general are larger in the long run; furthermore, to the extent these elasticities are endogenous, output-based rebating lowers them by reducing the incentives to pursue opportunities for substitutes.

Another thorny issue is not the tax, cap, or standard itself, but to what it applies. Before anything else, regulators must first define each product group. For delineations that are less obvious and products that are less uniform, special interests will stand to gain or lose a great deal by the definition. Producers of goods with relatively high emissions as byproducts would prefer their output be classified narrowly, so as to minimize deviation and maintain a high standard and subsidy. Meanwhile those with relatively low emissions would prefer a broader definition, grouping themselves with high emitters and a higher performance standard and maximizing their permit allocation.

In a multisector market for permits with separate allocation pools, output-based allocation can create gains from trade that would not otherwise exist. Although the model presented here is of different industries, the intuition carries over to other types of configurations: allocation pools might be geographic rather than sector-specific; the rule might even be for shares of total value rather than total output. The bottom line is that allocation based on production behavior creates a subsidy for that behavior, and differences in market conditions and allocation amounts create different effective subsidies. When permit trade is allowed between the pools, the incentives to overcomply are spread around, possibly reducing overall distortions from separate allocation incentives, but causing shifts in the distribution of compliance, costs, and prices that would not occur with other, nondistorting allocation systems. These shifts raise the futher question of how to set optimally the allotments (or standards or taxes) for each pool, given the different elasticities of demand and supply; would a type of Ramsey Rule take effect?

Finally, in addition to assessments of economic efficiency, issues of administrative expediency deserve mention. The information needed for implementing and enforcing a rebating scheme can be onerous. With an emissions tax or auctioned permit system, the government need only monitor emissions. With output-based rebating policies, the policy enforcer must know for each firm not only annual emissions, but also annual output and emissions *by product*. Furthermore, to achieve a target of emissions reduction, the policymaker must be able to forecast the equilibrium of both variables, inclusive of the effects of the implicit subsidy.[25]

This paper thus injects three major caveats into the debate over output-based rebating. The first question is, what are the opportunities for cost-effective output-substitution? For example, is energy demand highly inelastic, or will correct price signals induce consumers to adopt energy-saving practices? The more responsive is consumer behavior, the more wasteful is a subsidy program. Second, how difficult is it to define output and determing participating firms? If products are not uniform, or if eligibility is malleable, the effectiveness of the emissions or redistribution program can be compromised and administrative costs raised. Third, if imperfect participation is an issue, are the products of firms that cannot be regulated substitutes or complements? Rebating is a reasonable way to maintain competitiveness vis-a-vis unregulated firms only if their products are very close substitutes.[26]

From the point of view of efficiency, preferred environmental policies use market incentives and collect revenues with which the government can displace distortionary taxes. However, political realities must be taken into account, and policy adoption may require containing the rents within the affected industry. Output-based rebating can still clearly be preferable to command-and-control policies and no policy. But does it outperform other politically feasible allocation mechanisms? This question awaits better answers.

[25] And if the policymaker is reactive instead, adjusting performance standards or emissions caps sector by sector, firms will expect to have more of an impact on future performance standards, and market share will again come into play, creating different effective subsidies for different firms.

[26] The case of the Swedish NO_x tax may exemplify a reasonable situation: electricity is a uniform, well-defined product; its demand is fairly inelastic; and smaller competing producers of the identical product were exempt from regulation due to fixed monitoring costs.

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