JOURNAL OF ENVIRONMENTAL ECONOMICS AND MANAGEMENT **29**, 133–148 (1995)

# Transaction Costs and Tradeable Permits*

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Received January 12, 1994; revised April 5, 1994

Tradeable-permit systems are at the center of current interest and activity in market-based reforms of environmental policy, because these systems can offer significant advantages over conventional approaches to pollution control. Unfortunately, claims made for their relative cost-effectiveness have often been exaggerated. Transaction costs, which may be significant in these markets, reduce trading levels and increase abatement costs. In some cases, equilibrium permit allocations and hence aggregate control costs are sensitive to initial permit distributions, providing an efficiency justification for politicians' typical focus on initial allocations.


## 1. INTRODUCTION

The past five years have witnessed a dramatic increase in the attention given by policy makers to market-based environmental policy instruments as supplements to the conventional command-and-control standards that dominated the previous two decades of environmental law and regulation. One market-based instrument—tradeable emission permits—has been the center of much of this activity. The enthusiasm for this new approach has been so great that policy action and implementation has, in some cases, advanced beyond the understanding of some fundamental design issues. This paper seeks to illuminate an area that has received little attention, the effects of transaction costs on the performance of markets for pollution control.

The claims made for the cost-effectiveness of tradeable-permit systems have often exceeded what can reasonably be anticipated. Tietenberg [39] assimilated the results from 10 analyses of the costs of air pollution control, and in a frequently cited table, indicated the ratio of cost of actual command-and-control programs to least-cost benchmarks. Unfortunately, the resulting ratios (which ranged from 22.0 to 1.1) have sometimes been taken by others to be directly indicative of the potential gains from adopting specific ("cost effective") mechanisms such as tradeable emission permits. A more realistic and appropriate comparison would be between actual command-and-control policies and either actual trading programs

*Helpful comments were provided by Dallas Burtraw, Robert Dorfman, Lawrence Goulder, Robert Hahn, James Hines, Adam Jaffe, Joseph Kalt, Richard Morgenstern, Richard Newell, Wallace Oates, Thomas Tietenberg, Martin Weitzman, Richard Zeckhauser, seminar participants at Harvard University, two anonymous referees, and an associate editor. The author alone is responsible for remaining errors.



0095-0696/95 $12.00

(such as the EPA's bubble policy) or *reasonably constrained* theoretical permit programs [22].

### 1.1. *Markets for Pollution Control and the Potential Role of Transaction Costs*

More than two decades ago, Crocker [5] and Dales [8] developed the idea of using transferable discharge permits to allocate the pollution-control burden among firms or individuals; and Montgomery [29] provided a rigorous proof that a tradeable-permit system could, in theory, provide a cost-effective policy instrument for pollution control. A sizeable literature on tradeable permits has followed.[1]

A number of factors can adversely affect the performance of tradeable-permit systems, concentration in the permit market [15, 28], concentration in the output market [27], non-profit-maximizing behavior, such as sales or staff maximization [42], the preexisting regulatory environment [3], and the degree of monitoring and enforcement [23]. Additionally, several authors have commented on the potential importance of transaction costs in tradeable permit markets [18, 41, 2], although there has been only one attempt to allow for transaction costs within a model of tradeable-permit activity [42].[2]

In general, transaction costs are ubiquitous in market economies and can arise from the transfer of any property right because parties to exchanges must find one another, communicate, and exchange information. There may be a necessity to inspect and measure goods to be transferred, draw up contracts, consult with lawyers or other experts, and transfer title. Depending upon who provides these services, transaction costs can take one of two forms, inputs of resources—including time—by a buyer and/or a seller or a margin between the buying and selling price of a commodity in a given market. This paper focuses on the latter characterization of transactions costs. Hence, transaction costs in our analytical model can be thought of as the direct financial costs of brokerage services. This analytical approach is also empirically relevant, given the important role that brokers have played in the operation of actual permit systems [12, 19, 38].

We can identify three potential sources of transaction costs in tradable-permit markets: (1) search and information; (2) bargaining and decision; and (3) monitoring and enforcement.[3] The first source, search and information, may be the most obvious. Due to the public-good nature of some information, it can be underprovided by markets. Brokers step in, provide information about firms' pollution-con-

[1] Extensive surveys of the literature are found in Tietenberg [39, 40]. A more recent, though less comprehensive, survey is provided by Cropper and Oates [6].

[2] In this case, the author allowed for a dispersion between a constant selling price and a constant purchase price of permits, but did not pursue the implications of this and other forms of transaction cost functions for the performance of the respective markets. Kohn [24] examined the effect of transaction costs on the optimal (efficient) level of pollution control by assuming an arbitrary magnitude for transaction costs and comparing the consequent efficient level of control with that predicted when a pollution tax is employed. The model of transaction costs is itself problematic, since Kohn assumes that the magnitude of these costs increases with the level of control, as opposed to the level of exchange.

[3] All three categories can be interpreted as representing cost due to lack of information [7]. One alternative taxonomy is direct financial costs of engaging in a trade, costs of regulatory delay, and indirect costs associated with uncertainty of completing a trade [14]. In the context of this taxonomy, our analytical approach focuses on the first category—direct financial costs of trade.

trol options and potential trading partners, and thus reduce transaction costs, while absorbing some as fees.[4] Although less obvious, the second source of transaction costs, bargaining and decision, is potentially as important. There are real resource costs to a firm involved in entering into negotiations [24], including time and/or fees for brokerage, legal, and insurance services [20, 13]. The third source of transactions costs—monitoring and enforcement—can also be significant, but these costs are typically borne by the responsible governmental authority and not by trading partners, and hence do not fall within our notion of transaction costs incurred by firms.

There are two sets of circumstances in which transaction costs might be particularly high: (1) transfer is expensive for technological reasons; and (2) institutions are designed to impede trade. Both apply in the tradeable-permit context [13, 16], and in either case, transaction costs in the form of direct, financial costs of trading are frequently the result.

### 1.2. *Empirical Evidence of Transaction Costs in Permit Markets*

There is abundant anecdotal evidence indicating the prevalence of significant transaction costs in tradeable permit markets. Atkinson and Tietenberg [1] survey six empirical studies that found trading levels—and hence cost savings—in permit markets to be lower than anticipated by theoretical models. Liroff [26, p. 2] suggests that this experience with permit systems "demonstrates the need for ... recognition of the administrative and related transaction costs associated with transfer systems."[5] More specifically, Hahn and Hester [18] suggest that the Fox River water-pollutant trading program failed due to high transaction costs in the form of administrative requirements that essentially eliminated potential gains from trade. Likewise, under the EPA's Emissions Trading Program for criteria air pollutants, there is no ready means for buyers and sellers to identify one another, and—as a result—buyers frequently pay substantial fees to consultants who assist in the search for available permits [19, 16].

At the other extreme, the high level of trading that took place under the program of lead-rights trading among refineries as part of the EPA's leaded gasoline phasedown has been attributed to the program's minimal administrative requirements and the fact that the potential trading partners (refineries) were already experienced at striking deals with one another [18]. Hence, transaction costs were kept to a minimum and there was little need for intermediaries.

[4] In the newly established sulfur dioxide ($SO_2$) trading program under the Clean Air Act amendments of 1990, there is a substantial role for brokers for consulting with electrical utilities to help them understand their options. Brokerage firms maintain computer models used to predict the supply and demand for permits to provide forecasting services for utilities (Thomas Brooks, AER* X, personal communication, September 17, 1992). In local programs, such as the EPA's Emissions Trading Program, the broker may also carry out air-quality modeling required for trades between noncontiguous sources of nonuniformly mixed pollutants [25].

[5] Alternative explanations of low observed trading levels have also been advanced: lumpy investment in pollution-control technology, concentration in permit or product markets, the sequential and bilateral nature of the trading process (in the context of a nonuniformly mixed pollutant) leading to some initial trades that then preclude better trades from being carried out subsequently [1], and the regulatory environment [21, 3]. Some but not all of these "alternative explanations" of low trading levels can be viewed as special cases of transaction costs, broadly defined.

Similarly, Tripp and Dudek [41] claim that the success of the New Jersey Pinelands transferable development rights program was due to its design which minimized transaction costs (by the government taking on a feeless brokerage role).

Another source of indirect evidence of the prevalence of transaction costs in permit markets comes form the well-known bias in actual trading toward "internal trading" within firms, as opposed to "external trading" among firms. It has been hypothesized that the crucial difference favoring the internal trades and discouraging the external trades is the existence of significant transaction costs that arise once trades are between one firm and another [43, 19]. Finally, the existence of commercial brokers charging significant fees to facilitate transactions is another body of evidence.

## 2. TRADEABLE EMISSION PERMITS IN A MARKET WITH TRANSACTION COSTS

Consider first a cost-minimizing pollution control program for a uniformly-mixed, flow pollutant. For such a problem, we can focus on aggregate emissions per unit of time, where aggregate emissions, $E$, are simply the sum of emissions, $e_i$, from $N$ individual firms (or sources), where emissions from each source are the difference between unconstrained[6] emissions, $u_i$, and emission reductions, $r_i$. A cost-effective emission-control program is one that controls aggregate emissions from all sources at minimum total cost. It is well known that if the control cost functions are convex in their relevant ranges, then the necessary and sufficient conditions for cost minimization yield the result that the marginal cost of control will be the same among all sources that carry out positive levels of control.

To achieve this cost-effective allocation of the pollution-control burden, the government could conceivably establish a nonuniform (source-specific) standard to ensure that all firms would control emissions at the same marginal cost of control, but this would require detailed information about the costs faced by each source, which could be obtained by the authority only at very great cost, if at all. One way out of this impasse is a system of marketable emission permits. Consider a system under which the responsible authority allocates a total of $\bar{E}$ emission permits, $q_{0i}$ to each firm ($i = 1 \ldots N$).[7] Firms are free to trade permits among themselves and may meet government standards by exercising control and/or by possessing permits for their residual emissions. Under these conditions, the permit system achieves the cost-effective allocation of emissions control among sources, but without the government needing to acquire information about control costs; the final, equilibrium allocation of the control burden will be the same for any initial allocation of permits [29].

[6]The phrase "unconstrained emissions" is conditional upon prior pollution-control efforts. Hence, $u_i$ can be though of alternatively as *status quo* or *ex ante* emissions.

[7]To use the taxonomy of Tietenberg [40], we are considering an undifferentiated discharge permit, which gives any holder the same emission privileges; transfers among firms are on a one-for-one basis. There are three reasons for considering this simplest type of system: first, it is analytically the most convenient; second, the results generalize to the case of ambient permits for nonuniformly mixed pollutants; and third, simple emission permits have been the system used in nearly all applications. A new and potentially important exception is the RECLAIM trading program in the Los Angeles area, which imposes additional constraints when partners to trade are from different geographically defined regions; see South Coast Air Quality Management District [35].

## 2.1. *A Model of Permit Trading with Transaction Costs*

We now consider a market for emission permits in which costs are associated with the exchange of permits. Let $t_i$ denote the quantity of permits traded by source $i$,

$$t_i = |u_1 - r_i - q_{0i}|. \tag{1}$$

We define a common transaction cost function, $T(t_i)$, for which $T'(t_i) > 0$ and for which $T''(t_i)$ may be positive, negative, or zero-valued.[8] Each firm faces the problem,

$$\min_{\{r_i\}} \left[c_i(r_i) + p \cdot (u_i - r_i - q_{0i}) + T(t_i)\right] \tag{2}$$

$$\text{subject to:} \quad r_i \geq 0, \tag{3}$$

where $c_i(r_i)$ is pollution abatement (control) cost and $p$ is the price of permits. This problem yields the following solution:

$$\frac{\partial c_i(r_i)}{\partial r_i} + \frac{\partial T(t_i)}{\partial r_i} - p \geq 0 \tag{4}$$

$$r_i \cdot \left[\frac{\partial c_i(r_i)}{\partial r_i} + \frac{\partial T(t_i)}{\partial r_i} - p\right] = 0 \tag{5}$$

$$r_i \geq 0. \tag{6}$$

The environmental constraint is satisfied, but in contrast to the cost-effective and tradeable-permit solutions without transaction costs, we now find that rather than equilibrating marginal control costs among sources, the result of trading—for situations in which positive levels of control occur—is equilibration of the *sum* of marginal control costs and marginal transaction costs. Also, the total cost incurred by all regulated firms is no longer the simple sum of control costs but rather this amount plus total transaction costs.

## 2.2. *Consequences of Transaction Costs*

How should we think about the condition that the sum of marginal control costs and marginal transaction costs be equilibrated across sources? First, by the chain rule, we know that

$$\frac{\partial T(t_i)}{\partial r_i} = \left[\frac{\partial T(t_i)}{\partial t_i}\right] \cdot \left[\frac{\partial t_i}{\partial r_i}\right]. \tag{7}$$

[8] We assume that $T(t_i)$ is known with certainty. This is not unreasonable, but it is restrictive. Still, the function $T(t_i)$ is admittedly a simple characterization of the transaction cost function; later we add some structure to this to approximate empirical realities, but further work could lead to representations linked to other aspects of the taxonomy of transaction costs. For example, transaction costs are likely to be a function not only of the size of trades but of other attributes as well, since these costs should be affected by the relationship between trading partners. In particular, the anecdotal evidence summarized in the text suggests that transaction costs will be less for intrafirm (internal) than for interfirm (external) trades. This implies an avenue for further analytical work, allowing one component of transaction costs themselves to be endogeneous to a trader's decision problem.

If a source is a purchaser of permits ($u_i - r_i - q_{0i} > 0$), then $t_i = u_i - r_i - q_{0i}$, and so in this case

$$\frac{\partial t_i}{\partial r_i} = -1 \quad \text{and} \quad \frac{\partial T(t_i)}{\partial r_i} = -\frac{\partial T(t_i)}{\partial t_i}. \tag{8}$$

If a source is a seller of permits ($u_i - r_i - q_{0i} < 0$), then $t_i = -u_i + r_i + q_{0i}$, and we have

$$\frac{\partial t_i}{\partial r_i} = 1 \quad \text{and} \quad \frac{\partial T(t_i)}{\partial r_i} = \frac{\partial T(t_i)}{\partial t_i}. \tag{9}$$

By substituting the results from Eq. (8) or Eq. (9) into Eq. (5), it is clear that if marginal transaction costs are nonzero, the original "cost-effective equilibrium," where marginal control costs are equated across all sources, will not be achieved.[9] The marginal control costs experienced by the permit buyer exceed those experienced by the permit seller by the amount of marginal transaction costs that the trading partners bear.

This can be perceived most readily in the context of a two-source scenario. Assuming for the time being that marginal transaction costs are constant (i.e., that $T''(t_i) = 0$) and that these costs ($T' = \alpha$) are paid directly by the seller of permits (as with most brokerage fees), we can view the marginal transaction costs and the new equilibrium condition in Fig. 1,[10] where the outcome of trading is the pollution-control allocation $r_A^*$, as different from the equilibrium without transaction costs, $r^*$. If the initial allocation of control responsibility is located to the right of the posttrading equilibrium with transaction costs, $r_B^*$, then the locus of points representing the sum of marginal control costs and marginal transaction costs is found above source 2's control cost function (achieving outcome $r_B^*$ in Fig. 1). The equilibria differ because the identities of buyer and seller have switched.[11]

[9]Since some or all transaction costs may be real resource costs, we should really refer to the original equilibrium as "the cost-effective equilibrium in the absence of transaction costs." Furthermore, to whatever degree transaction costs reflect real resource costs, their existence also affects the optimal level of control [11, 24]. We use the abbreviated description of the equilibria simply for convenience, but the distinction should not be overlooked. To whatever degree transaction costs are real resource costs, they will result in a different equilibrium, but one that is still cost-effective, although it will necessarily involve greater aggregate costs than the cost-effective equilibrium in the absence of transaction costs. It might be said that this implies that the message here is not about transaction costs per se, but rather about correctly measuring the true costs of control. The response, as will become clear below, is that the crucial issue is not whether we call this category of typically omitted costs "transaction costs" or "other control costs," rather, it is whether these costs are a function of the degree of control—as with control or abatement costs—*or* a fixed and/or variable function of trading activity itself.

[10]In Fig. 1, the vertical axis is in monetary terms; control for source 1, $r_1$, increases to the right; control for source 2, $r_2$, increases to the left; all points on the horizontal axis represent compliance with the aggregate emission constraint. An interior solution is depicted where marginal costs are equilibrated at a positive level of control for both sources. If the initial allocation of emission permits is $q_{01}$ and $q_{02}$, respectively, then in the absence of trades the emission control *required* by each of the two sources is implicitly $r_i = u_1 - q_{01}$ for $i = 1, 2$. By taking the initial allocation as a new vertical axis, the two truncated marginal control cost functions yield permit supply and demand functions, and by horizontally summing all such relationships, permit market supply and demand can be examined.

[11]This result that the trading equilibrium is sensitive to the initial allocation in the presence of transaction costs is, of course, fully consistent with the Coase Theorem, which states that in the presence of transaction costs, the anticipated outcome from a process of bilateral negotiation is variant with respect to the initial assignment of property rights [4]. In Fig. 1, if the initial allocation of permits is between $r_A^*$ and $r_B^*$, then no trading will take place and the initial allocation *is* the final equilibrium.

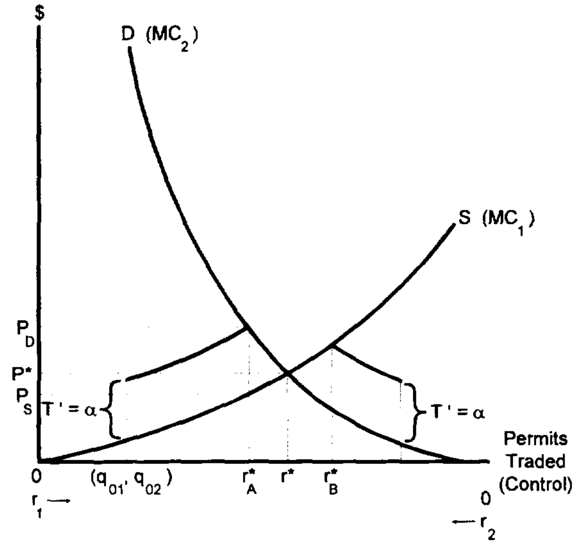


FIG. 1. Constant marginal transaction costs.

These effects are not dependent upon the marginal transaction costs being constant. The effect of transaction costs is unambiguously to decrease the volume of permit trading, regardless of the specific forms that the marginal control cost functions and transaction cost functions take, as long as the marginal control cost functions are nondecreasing over the relevant ranges.[12] As transaction costs increase, the price received by sellers is depressed and the price paid by purchasers is driven upward. Analogous with the well-known tax-incidence result, the degree of these price effects is dependent upon the relative elasticity values. The change in price will be greater for relatively high-cost controllers, essentially because high-cost (inelastic) controllers have less flexibility in decision making.[13]

This leads naturally to the question of how the burden of transaction costs is shared between permit suppliers and demanders. Following the analogy with tax incidence, it is not surprising to find that the gains from trade accruing to both sides of the market decrease as a consequence of transaction costs, and that the distribution of the burden is a function of the relative elasticities of the underlying cost-of-control functions. The burden (loss of potential gains from trade) of transaction costs will fall most heavily on the higher cost controllers (*steeper*

[12]A proof of this is found in [36]. In the case of constant marginal transaction costs, whether trading will take place depends upon whether the difference between the marginal control costs of the two sources at the initial allocation is greater than the transaction costs of trading the minimal size permit. In those situations in which trading takes place, the magnitude of individual trades will be less than in the absence of transaction costs. Hence, constant marginal transaction costs may reduce the total number of trades (particularly if combined with significant fixed transaction costs) and will certainly reduce aggregate trading volume.

[13]Because these results are analogous to well-known tax-incidence results, derivations are not provided in this paper. Instead, the reader is referred to [36]. The effect of transaction costs is also parallel to the effect of transportation costs, which result in a single market price being replaced by a cluster of prices. By "high-cost controller," we mean the source with the steeper marginal control cost function.

marginal control-cost functions), regardless of who may actually pay direct transaction costs, such as brokerage fees.[14]

In general, in the presence of transaction costs, if the initial allocation deviates from what would be the equilibrium allocation in the absence of transaction costs, total expenditures on pollution control (even putting aside transaction costs themselves) will exceed the cost-minimizing solution. Thus, transaction costs reduce welfare—partly by absorbing resources directly and partly by suppressing exchanges that otherwise would have been mutually beneficial.

This brings us to the central question, can the initial allocation of permits affect the outcome of trading (putting aside the most obvious effect of the initial allocation being located on one side or the other of the cost-effective equilibrium)? In other words, does the frequently restated finding of Montgomery [29], that the equilibrium allocation of control and hence the aggregate costs of control are independent from the initial permit allocation, still hold in the presence of transaction costs? The answer is "it depends." To see this, we examine again a two-source model in which source 1 is a potential permit seller and source 2 is a potential buyer. We assume, without loss of generality, that transaction costs are paid by sellers.

For positive levels of control by two sources, Eqs. (5) and (9) yield the market equilibrium condition

$$c_1'(r_1) + T'(t_1) = c_2'(r_2), \tag{10}$$

where $t_1 = -u_1 + r_1 + q_{01}$. In order to investigate the effect of the initial allocation on the equilibrium outcome, we differentiate both sides of Eq. (10) with respect to the primary variables, $r_1$, $r_2$, and $q_{01}$,

$$c_1''(r_1) \cdot dr_1 + T''(t_1) \cdot \frac{\partial t_1}{\partial r_1} \cdot dr_1 + T''(t_1) \cdot \frac{\partial t_1}{\partial q_{01}} \cdot dq_{01} = c_2''(r_2) \cdot dr_2. \tag{11}$$

Any change in $t_1$ is necessarily equal to a corresponding change in $t_2$. Since $u_1$ and $u_2$ do not—by definition—change and since any change in $q_{01}$ must of necessity be equal to $-1$ times the change in $q_{02}$, it must be the case that any change in $r_1$ is equal to $-1$ times the change in $r_2$. In other words, holding constant the total quantity of permits, aggregate emissions reductions must be unchanged. Hence, we can substitute $-dr_1$ for $dr_2$ in Eq. (11). Also, note that from the definition of $t_1$, we know that

$$\frac{\partial t_1}{\partial r_1} = \frac{\partial t_1}{\partial q_{01}} = 1. \tag{12}$$

[14] If transaction costs are paid by permit buyers, then as Eq. (8) illustrates, the locus of points representing the sum of marginal control costs and marginal transaction costs is found *below* the respective control cost functions. The respective equilibria, however, are identical in the two cases. This suggests an alternative approach to modeling transaction costs in tradeable permit markets, namely a game theoretic approach, allowing for the presence of bilateral monopoly. In that context, the division of the gains from trade—with or without transaction costs—will depend upon possible information asymmetries [30].

Thus, rearranging terms, we rewrite Eq. (11) as

$$[c_1''(r_1) + T''(t_1) + c_2''(r_2)] \cdot dr_1 + T''(t_1) \cdot dq_{01} = 0. \tag{13}$$

Dividing through by $dq_{01}$, we have

$$\frac{dr_1}{dq_{01}} = \frac{-T''(t_1)}{[T''(t_1) + c_1''(r_1) + c_2''(r_2)]}, \tag{14}$$

enabling us to examine the impact of the initial allocation on the equilibrium control level,

$$\text{if } T''(t_1) = 0 \quad \text{then } \frac{dr_1}{dq_{01}} = 0 \tag{15}$$

$$\text{if } T''(t_1) > 0 \quad \text{then } \frac{dr_1}{dq_{01}} < 0 \tag{16}$$

$$\text{if } T''(t_1) < 0 \quad \text{then } \frac{dr_1}{dq_{01}} > 0. \tag{17}$$

If marginal transaction costs are constant ($T''(t_1) = 0$), the usual result in the absence of transaction costs still holds; the initial allocation of permits has no effect on the equilibrium allocation of control responsibility and aggregate control costs.[15]

On the other hand, if marginal transactions costs are increasing ($T''(t_1) > 0$), then the initial allocation would seem to affect the posttrading outcome (Fig. 2). In particular, Eq. (16) implies that as we increase the allocation of emission permits to a source (reduce its initial control responsibility), its equilibrium control level will be reduced, thus increasing the departure of the post-trading equilibrium outcome from the "cost-effective equilibrium," driving up aggregate control costs in the process.[16] Although increasing marginal transaction costs, on their own, are not sustainable (since parties would simply split their transactions into smaller trades to economize), increasing marginal transaction costs *are* sustainable if combined with sufficient fixed transaction costs.[17]

[15]Although direct abatement costs are therefore unaffected, aggregate transaction costs themselves change as the initial allocation of control responsibility becomes more or less remote from the cost-effective equilibrium allocation.

[16]As we shift the initial allocation of control responsibility in Fig. 2 from $r_{0A}$ to $r_{0B}$, the trading equilibrium also changes (from $r_A^*$ to $r_B^*$), because $T''(t_i) \geq 0$. As a result of employing the initial allocation $r_{0B}$ instead of $r_{0A}$, both transaction costs *and* deadweight loss have increased.

[17]A further comment on the case of fixed transaction costs is merited. If $T(t_i) = \alpha$ and $T'(t_i) = 0$, then trading will occur, *ceteris paribus*, in the simple $N = 2$ model if potential gains from trade exceed $\alpha$ at the initial allocation of permits (and control responsibility); otherwise it will not. In this case, sources may have incentives to reduce the number of separate trades but the equilibrium level of each trade is not affected. In the aggregate, the result is decreased trading volume. On its own, the case of fixed transaction costs is analytically identical to Hahn's [17] examination of the EPA's "20% rule" on criteria air-pollutant trading; if all sources engage in trading, the cost-effective equilibrium allocation of the control burden among sources will be achieved, but in the presence of fixed transaction costs, there may be fewer trades than would otherwise occur, in which case the cost-effective allocation will not be achieved.

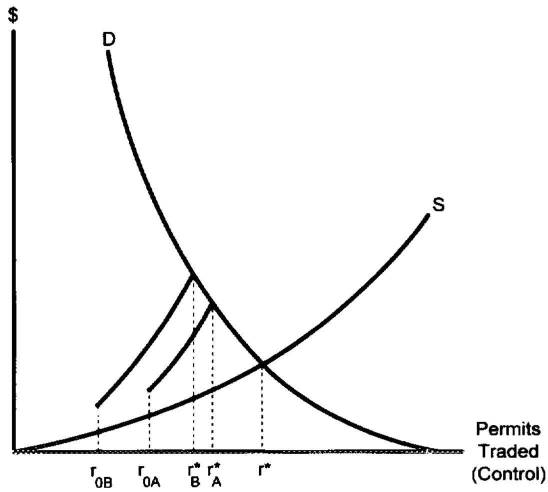


FIG. 2. Increasing marginal transaction costs.

Finally, decreasing marginal transaction costs might occur where brokers offer quantity discounts[18] on their services. In this case ($T''(t_1) < 0$), a shift in the initial permit allocation *away* from the cost-effective equilibrium leads to a posttrading outcome that is *closer* than otherwise to the cost-effective equilibrium[19] (Fig. 3). What may appear to be a counterintuitive result is simply due to the fact that decreasing marginal transaction costs mean that there are scale economies of trading of which firms can take advantage.[20]

Thus, in the presence of transaction costs, the initial distribution of permits can matter in terms of efficiency, not only in terms of equity (Table I).[21] In his 1972 paper, Montgomery [29] observed that because of the independence of the equilib-

[18] Typical volume discounts are expressed in terms of average, not marginal costs. If fixed costs are present, there could be declining average costs without declining marginal costs, but if there are no fixed costs, then declining average and declining marginal costs obviously imply one another. A referee points out that at the market level, decreasing marginal transaction costs could also be due to positive information externalities (associated with larger trading volumes) that systematically lower transaction costs. See Section 3.1.

[19] When $T''(t) < 0$, the denominator in Eq. (14) is of ambiguous sign, depending upon the relative magnitudes of the slopes of the marginal transaction cost function and the marginal control cost functions. Since we assume that the second-order condition for the permit-trading problem is satisfied, however, the denominator must be positive; thus the apparent ambiguity is removed.

[20] This happens unless marginal transaction costs are reduced to zero before the cost-effective equilibrium is reached, in which case costly trading is followed by costless trading, and the cost-effective equilibrium is achieved. Hence, moving the initial allocation away from the cost-effective one either will cause the final equilibrium to be closer to the cost-effective equilibrium or will have no effect, in which case the final equilibrium is the cost-effective one.

[21] One other potentially important type of transaction cost is associated with percentage brokerage fees. Analogous to the *ad valorem* tax, such constant percentage brokerage fees appear as constant marginal transaction costs to individual permit buyers or sellers (who take the permit price to be exogenously determined), but at the level of market supply and demand for permits, this type of brokerage fee structure looks something like declining marginal transaction costs. However, in this case, a change in the initial permit allocation has no effect on the final equilibrium, since the transaction cost function does not itself shift.

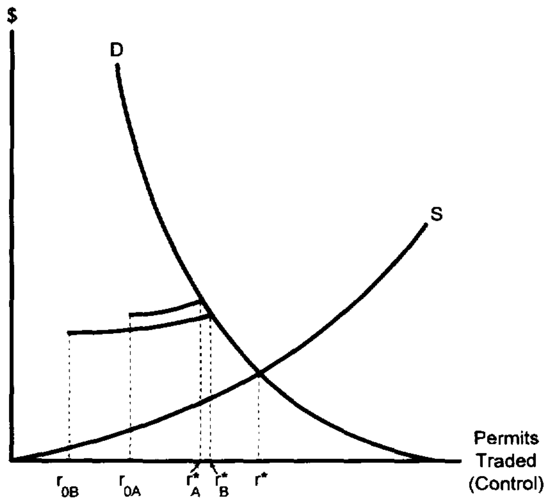


FIG. 3. Decreasing marginal transaction costs.

rium from the initial allocation, "the management agency can distribute licenses as it pleases. Considerations of equity, of administrative convenience, or of political expediency can determine the allocation. The same efficient equilibrium will be achieved." Not so, potentially, in the presence of transaction costs. This can reduce the discretion of the environmental agency and the legislature, and may thereby reduce the political attractiveness and feasibility of a tradeable permit system.

## 3. IMPLICATIONS FOR PUBLIC POLICY

### 3.1. *Instrument Choice*

At the most basic level, the message of this analysis is obvious; choices between conventional, command-and-control environmental policies, and market-based in-

TABLE I
Consequences of Transaction Costs

| Form transaction costs | Example | Effect on number of trades | Effect on size of individual trades | Effect on aggregate quantity traded | Sensitivity of posttrading equilibrium to initial allocation |
|---|---|---|---|---|---|
| Fixed cost only | \$1000 per trade | Decrease or no change | No change | Decrease or no change | $dr/dq_0 > 0$ |
| Constant MTC | \$10 per ton of $SO_2$ traded | Decrease or no change | Decrease | Decrease | $dr/dq_0 = 0$ |
| Increasing MTC | \$10 × (ton traded)$^2$ | Decrease or no change | Decrease | Decrease | $dr/dq_0 < 0$ |
| Decreasing MTC | \$10 × (ton) − .001 × (ton)$^2$ | Decrease or no change | Decrease or no change | Decrease or no change | $dr/dq_0 > 0$ |
| Value of trade | 0.10 × value of trade | Decrease or no change | Decrease | Decrease | $dr/dq_0 = 0$ |

struments ought to reflect the imperfect world in which these instruments are applied.[22] But even if transaction costs prevent significant levels of trade from occurring, aggregate costs of control will most likely not exceed those of a conventional command-and-control approach. A trading system *with no trading* taking place will likely be less costly than a technology standard (because the trading system provides flexibility to firms regarding their chosen means of control) and no more costly than a uniform performance standard. On the other hand, it is possible that in some circumstances the total cost of compliance (including transaction costs) of a tradeable permit system could exceed (depending upon the initial allocation of permits) the costs of a uniform performance standard (which exhibited small administrative costs). There is no simple answer, no policy panacea; case-by-case examinations are required.

Nevertheless, some general implications of the analysis do emerge. Transaction costs increase the aggregate costs of control indirectly by reducing total trading volume and directly by adding to total costs of control. However, these effects should be ameliorated somewhat in markets with relatively large number of potential trading sources. As the pool of potential trading partners increases, it should be easier for sources to identify potential trading partners, thereby lowering transaction costs. A larger number of firms can mean more frequent transactions, generating more information, and thereby reducing uncertainty[23] [31]. Hence, due to possible transaction-cost effects (and due to the likely effects of market concentration and strategic behavior), we ought to be least confident of relying on tradeable-permit system in situations of thin markets.

Economists have tended to give greater emphasis to the symmetry between tradeable permits and pollution charges[24] than to their differences, although the two approaches are not symmetric under conditions of uncertainty [44], in the presence of transaction costs, or under a number of other conditions [37]. Analyses that have compared taxes and permits have assumed zero transaction costs, which is troubling considering the evidence that these costs are common in permit markets. Systems of pollution taxes, of course, can also involve substantial administrative costs, both fixed (per firm) and variable [32]. Hence, these instruments should also be compared only on a case-by-case basis.

An interesting implication of the analysis in regard to the choice between taxes and permits comes from our finding that the initial allocation of permits affects the final equilibrium when marginal transaction costs are nonconstant. Recall that the major advantage of tradeable permits over command-and-control *and* over emission taxes is that the government can achieve a given aggregate target cost effectively *without* knowing anything about individual firms' costs of pollution control. However, when transaction costs exist, operating an efficient permit

[22] The point that it is wrong to compare an actual, imperfect institution with a theoretically ideal one goes back at least to Coase [4]. A referee notes that Demsetz [9] objected to comparisons of actual imperfect markets with idealized governments; our point may be said to be the reverse—actual imperfect government should not be compared with idealized markets. Since transactions costs are essentially the market counterpart of administrative costs in command-and-control systems, both need to be considered.

[23] In a model with many sources, transaction costs would be a function of the size of trades and a function of total trading volume in the market, if trades produce positive informational externalities.

[24] The assumed symmetry is between taxes and auctioned permits, and between freely allocated permits and taxes with specific redistribution of revenues to selected firms [10].

market means distributing permits initially so that the sum of control costs and transaction costs is minimized. Clearly, the initial allocation that minimizes this sum is the solution to the least-cost pollution control problem in the absence of transaction costs (since if permits where thus distributed, no trading would occur, and transaction costs would also be minimized). But to solve this problem, the government must know firms' cost-of-abatement functions. Unless transaction costs are prohibitive, tradeable permits will retain an information advantage over command-and-control approaches and emission taxes, but that advantage will be less in the presence of significant transaction costs than otherwise.

### 3.2. *Instrument Design*

Three sets of tradeable-permit design issues stand out as being particularly affected by the presence of transaction costs. First, there is the issue of what point in the "product cycle" to regulate pollution. The simplest systems (whether tradeable permits or other instruments) focus on *inputs* to the production process, such as the lead content of gasoline or the carbon content of fossil fuels. One step toward greater sophistication but also substantially greater administrative complexity and transaction costs is represented by *emissions* permit trading. Further in the same direction is *ambient* or *concentration* permit trading. And further still would be *exposure* trading [34], and finally *risk* trading [33]. As we move along this path, each system may come closer to a theoretical ideal, but each system is also likely to bring greater public costs associated with monitoring and enforcement and greater private transaction costs. Indeed, these practical considerations provide one explanation of why, contrary to the models going back to Montgomery [29], only input and emissions trading have actually be adopted by public authorities.[25]

Second, given the close linkage between information problems and transaction costs, another obvious implication is that programs should be designed to provide needed information. In principal, there are three ways this could be done, government can take actions that directly reduce regulatory uncertainty, barriers to private brokerage services can be reduced, and allowance can be made for the development of futures markets. In the first case, at a minimum, the government authority can avoid creating regulatory barriers (such as requirements for government preapproval of trades) that drive up transaction costs and discourage trading.[26] More actively, the government can seek to reduce market uncertainty by taking on a brokerage role—supplying information about potential buyers and sellers, and thus helping sources identify one another [41].

Private provision of brokerage services can also play an important role in information provision. Thus, although commercial brokers can certainly be recipients of transaction costs, their activities reduce transaction costs below what they would otherwise be. Intermediaries, in general, can contribute to social welfare by

[25]As noted above, the new RECLAIM trading program for $SO_x$ and $NO_x$ in the Los Angeles area provides a partial exception, in the sense that due to concerns about the nonuniformly mixed nature of the pollutants in the airshed, additional constraints have been placed upon emissions trading.

[26]Regulatory uncertainty may also include "general program uncertainty" about whether a particular program will be maintained in the future, and uncertainty about how a new trading program fits into the preexisting regulatory environment (as in the case of the $SO_2$ allowance trading system among regulated electrical utilities).

helping parties economize on transaction costs. Brokers can play the role of consultants, adding value by understanding the regulatory process and by maintaining information about prospective suppliers and demanders of permits. Under the more conventional function of bringing together buyers and sellers ("brokering deals" by matching buy orders and sell orders), these firms both absorb and reduce transaction costs. Finally, brokers may assume risk by buying, holding, and selling permits.

A third and final set of design issues is associated with determining the initial allocation of permits, a subject that takes on added significance in the presence of transaction costs. For any tradeable permit system, political feasibility can be established or destroyed over this single aspect of design. Because of the necessity of establishing a constituency for a proposed system, the route that has inevitably been chosen for distributing permits has been free distribution (endowment).[27] This politically attractive route enables all sorts of initial allocations to be devised in order to win support for a program.

Typically, economists have been quite agnostic about these alternative allocations, because they have considered them to have only distributional implications, since it has been assumed that aggregate abatement costs would be unaffected. As we have seen, however, this may not be true when transaction costs are present. Thus, a successful attempt to establish a politically viable program through specific permit allocations can actually result in a program that will be far more costly than promised. This may argue for the economist's favorite permit-allocation mechanism—auctions, an approach that becomes even more attractive in the presence of transaction costs. We are left, however, with the reality that political barriers against permit auctions and political incentives in favor of all sorts of free distributions are likely to remain in place for the foreseeable future.

The general message for public policy that arises when we begin to consider the presence of transaction costs in markets for tradeable permits is that "the devil is likely to be in the details." Although the existence of transaction costs may make the choice between ambient and emission permits more obvious, it may well make the choice between conventional approaches and permits more difficult because of the ambiguities that are introduced. Likewise, the supposed symmetry of taxes and permits becomes questionable, and the need to compare these instruments on a case-by-case basis becomes more compelling. Finally, with transaction costs as with other departures from frictionless markets, greater attention should be paid to the details of design of specific systems, in order to lessen the risk of overselling these policy ideas and in order to create systems that stand a chance of being implemented successfully.

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[27]As Zeckhauser [45] has noted, the distribution of gains and losses arising from a policy is likely to have greater effects on whether that policy is adopted (in a democratic society) than the magnitude (or even the sign) of net benefits.

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