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Comparative Analysis of Air Pollution Regulation Policies via Property Rights and Transaction Cost Theory

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Abstract

This paper compares alternative policies for the regulation of pollution. Emission charges, emission standards, and tradable emission permits are addressed from the perspective of property rights and transaction cost theory. In the first section of this paper, the supply and demand curves of pollution under each policy condition are associated with different property right structures of alternative policies. The property right distribution is a key factor in determining the strength and weakness of alternative policies in terms of the polluter-pay-principle, acceptability, incentive intensity, and transaction costs.

The transaction cost analysis of Williamson has been extended to encompass the governance structures of public sector transactions, and identifies regulation as one of the six types of public sector transaction: procurement, redistributional, regulatory, sovereign, judicial, and infrastructure. The second part of this paper evaluates the transaction costs of regulatory policies by comparing ex ante costs such as information and negotiation costs, as well as ex post costs, such as monitoring and enforcement costs. One key attribute determining the relative size of the transaction costs of tradable emission permits is the emissions monitoring technology used, most notably the CMS (Continuous Monitoring System). Some guiding principles for choosing policy instruments are also suggested in this paper on the basis of our comparison of alternatives in terms of the polluter-pay-principle, acceptability, incentive intensity, and specifically, transaction costs.

Key words: air pollution, regulation, property rights, transaction costs

INTRODUCTION

A comparative analysis of alternative policy instruments for the regulation of air pollution is not a novel research topic. The subject has been the focus of a number of previous works, and has been introduced in a variety of environmental economics textbooks, such as that of Tietenberg (2006b). Although this paper is based on that previous body of literature, it also further develops its analysis from the perspective of new institutional economics--in particular, from the perspective of property rights and transaction costs theory.

Environmental economics textbooks generally hold that market-based policy instruments such as emissions charges and tradable emission permits have an advantage over direct regulation such as emissions standards, in that market-based instruments allow each polluter to select the most efficient method for pollution reduction, rather than imposing a uniform emissions reductions regime. This paper also generally concedes the efficiency of market-based policy instruments. However, there are some other significant factors to consider when choosing policy instruments designed to regulate pollution. This paper discusses some of the principles of choosing policy instruments from the perspectives of property rights and transaction costs theory.

The policy alternatives to be compared in this paper include tradable emission permits, emissions charges, and emissions standards. Tradable emissions permits require society to set a quota, a maximum amount of pollution to be allowed for each source. Sources can vary in terms of the numbers of permits they hold, and hence their emissions levels, by buying and selling from and to other sources (Dales, 1968; Tietenberg, 2006a). An emission charge is a fee that is levied on each unit of pollutant emitted into the air or water. An emission standard is a legal limit placed on the amount of a pollutant that individual source is permitted to emit (Tietenberg, 2006b). In particular, tradable emission permits will be discussed in detail, with an eye toward investigating the implications of various permits allocation methods from the perspectives of property rights and transaction cost theory. Additionally, Coasean property rights allocation will be an important component of the analysis, since the subject has been discussed fairly widely with regard to the property rights approach (Coase, 1960).

The structure of this paper is as follows. After introducing the research background in this section, the second section explains alternative policies for the regulation of air pollution, in particular, emission charges, emission standards, and tradable emission permits via a property rights approach. The supply and demand curves of pollution evidence different property rights structures resulting from alternative policy instruments. The third section compares the transaction costs of the alternative policies. The transaction costs are classified into *ex ante* costs such as information costs for permits allocation, as well as *ex post* costs such as monitoring costs. It also addresses the key attributes affecting the relative size of transaction costs among alternative regulatory options. In the final section, some principles for choosing an optimal policy instrument for the regulation of air pollution are discussed, as well as the possibility of the extension of these instruments to other pollution issues.

COMPARISON OF ALTERNATIVE AIR POLLUTION REGULATION POLICIES: A PROPERTY RIGHTS APPROACH

Figure 1 shows a demand and supply curve of pollution. The downward demand curve shows that the lower the price of polluting is, the more firms will elect to pollute. In cases in which no policy intervention exists, polluters can emit pollution without paying any price; this is equivalent to the open access situation in the 'tragedy of the commons' (Hardin, 1968). Therefore, as demonstrated in Figure 1, the supply curve (private marginal cost) of pollution is horizontal at a price of zero with the maximum emissions of a natural capacity limit (e^c). In Figure 1, the demand curve and supply curve of pollution meet at e^m, which is a market equilibrium of pollution. In figure 1, the social marginal cost (SMC) of pollution, which equals the damage cost for each additional unit of pollution, is

assumed to be constant regardless of the amount of emissions. The social optimal quantity of pollution is represented by e^o in this figure, at which the demand curve crosses the social costs of pollution. The result of a 'laissez-faire' policy is excessive emissions over the socially optimal level ($e^m > e^o$).

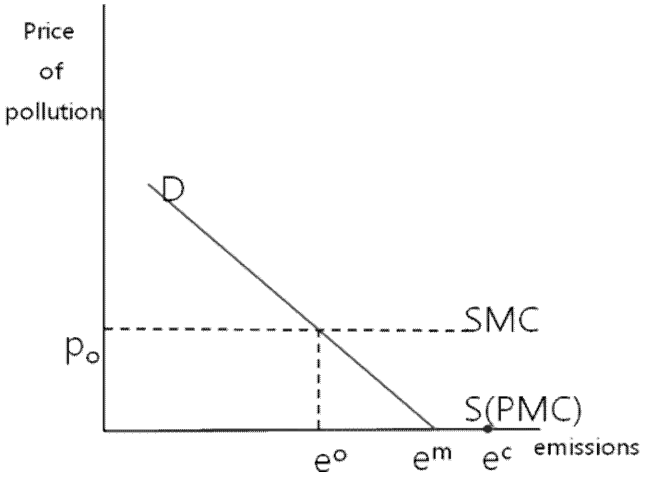


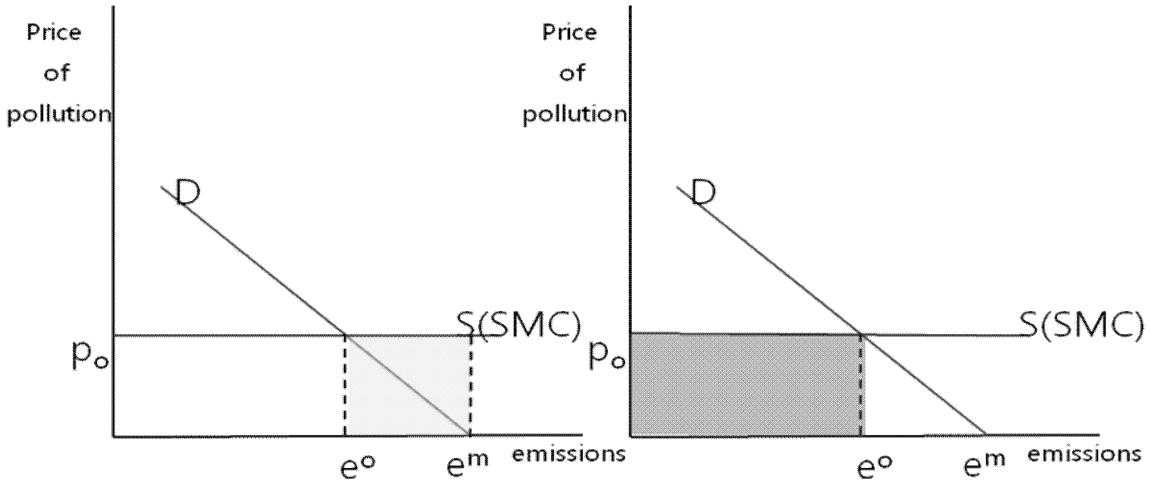
Figure 1. Equilibrium of pollution under no policy intervention.

By implementing regulatory policies or allocating pollution rights to either polluters or pollution recipients, the socially optimal level of pollution (e^o) can be achieved. Although a variety of alternative policy instruments have been developed to achieve the socially optimal level of pollution, each policy results in different property rights structures, which raise an important implication regarding the choice of policy instruments (Lidecap, 1989; Ostrom, 1990, 2005). In the following section, we compare the distributions of property rights that result from the implementation of each policy instrument. All cases are designed to lead to the socially optimal emission level (e^o). The policy instruments to be compared herein are: Coasean property rights assignment to either polluters or recipients, tradable emission permits by free allocation or by auction, emission charges (subsidies), and emission standards. On the basis of the property right structures of alternative policy instruments, the key principles relevant to the selection of policy instruments for the regulation of pollution will be suggested in the following discussion. In this paper, regulatory agencies are supposed to represent the interests of pollution recipients. For example, paying charges by polluters to regulatory agencies is assumed to be equivalent to wealth transfer from the polluters to the recipients.

First, the Coasean allocation of property rights of polluting is illustrated in Figure 2. Coasean cases basically contain two different property right structures: one in which pollution rights belong to polluters and the other in which pollution rights belong to the pollution recipients. As the Coasean theorem states, when no significant transaction costs are assessed, the two parties (polluters and recipients) can reach the socially optimal quantity of pollution (e^o) without regard to whom the initial pollution rights belong.

Figure 2 shows the distribution of property rights when pollution rights are assigned to polluters (a) and when pollution rights are assigned to recipients (b). Although the amounts of emissions are equal regardless of the initial allocation of pollution rights, the welfare of polluters and recipients will be significantly affected by the manner in which the initial allocation is made. The amount of wealth transfer from pollution recipients to polluters in case (a) equals $p^o(e^m - e^o)$ (light gray area in the figure). P^o is the social price of pollution, which equals the damage costs incurred due to each additional unit of pollution. As a matter of fact, p^o is the maximum price recipients are willing to pay for an

additional unit of emissions abandoned by polluters. The amount of wealth transfer from polluters to recipients in case (b) equals $p^o e^o$ (gray area in the figure). P^o is the social price of pollution as well as the minimum price that recipients are willing to accept for an additional unit of emissions emitted by polluters. If b' $(0 < b' < e^m)$ is allocated to polluters as a pollution right, wealth transfer to recipients from polluters will equal $p^o(e^o - e')$ (Krutilla, 1999).

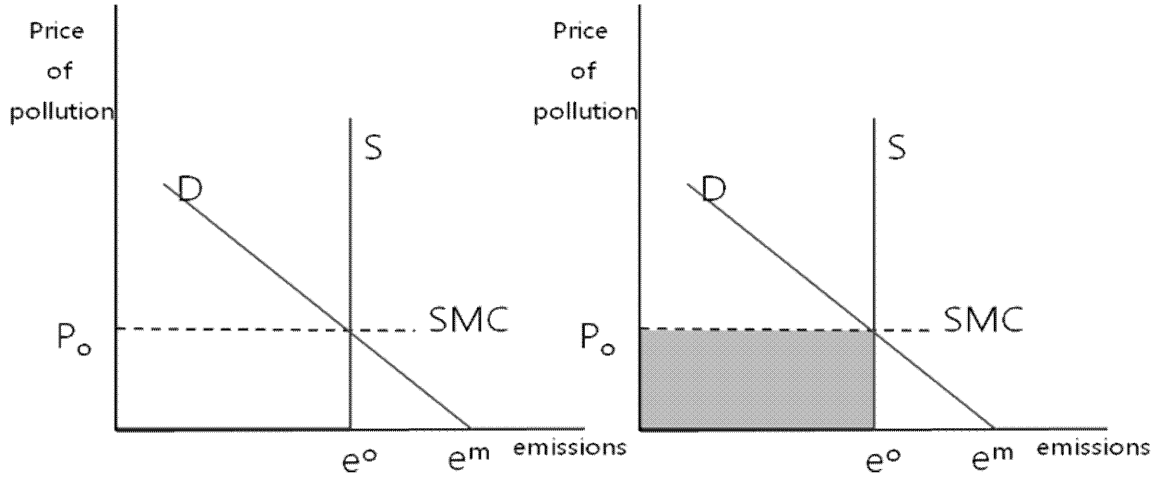


(a) assignment to polluters (b) assignment to recipients

Figure 2. Property right structures under Coasean allocation of pollution rights.

Second, property right structures of tradable emission permits are illustrated in Figure 3. The amount of permits allocated to polluters determines the distribution of property rights between polluters and pollution recipients. However, the method of allocating permits also affects the distribution of property rights. In the case of the free allocation of e^o to polluters (grandfathering), all the property rights of emission permits belong to the polluters, and the right to the remaining emissions $(e^m - e^o)$ belongs to the recipients (Figure 3a). Thus, polluters are permitted to emit pollution only up to e^o. No wealth transfer occurs between polluters and recipients and the initial distribution of pollution rights remains unchanged. If the amount of e' is allocated to polluters for free, the remaining emissions $(e^m - e')$ belong to the recipients (Krutilla, 1999).

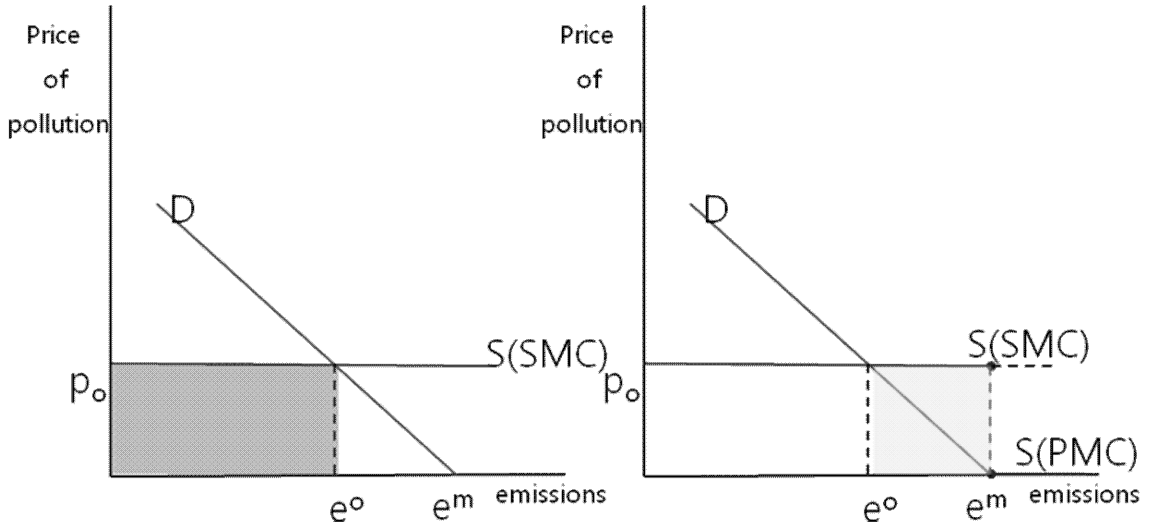
If the amount of e^o is allocated by auction, under perfect information conditions, the equilibrium auction price would be p^o. Therefore, polluters must pay the entire cost of pollution $(p^o e^o)$ (gray area in Figure 3b).



(a) permits allocation by grandfathering (b) permits allocation by auction

Figure 3. Property right structure under tradable emission permits.

Third, Figure 4 shows property right structures of emissions charges and subsidies. If an emission charge is levied by the amount of marginal damage cost, equilibrium price and quantity of pollution would be p^o, e^o and polluters have to pay the whole costs of emissions e^o, p^oe^o. In this case the initial assignment of pollution rights is all given to recipients and polluters earn pollution rights by paying compensation of p^oe^o (gray area in Figure 4a). In case of emission subsidies, the initial assignment of pollution rights of e^m is all given to polluters and they abandon pollution rights of (e^m-e^o) by being compensated (subsidized) by p^o(e^m-e^o) (light gray area in Figure 4b). There is no compensation for emissions over e^m, which is shown by a horizontal supply curve of pollution at zero price over e^m in Figure 4b.



(a) emission charges (b) emission subsidies

Figure 4. Property right structure under emission charges/subsidies.

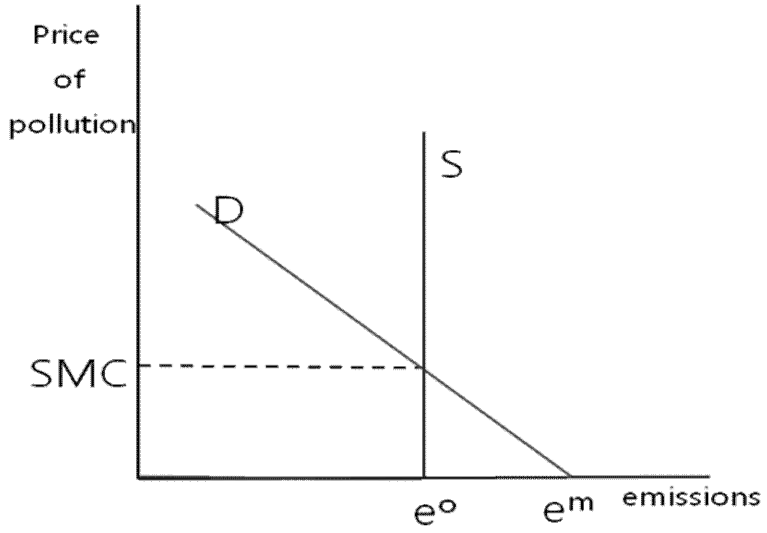


Figure 5. Property right structure under emission standards.

The property right structure of emission standards is illustrated in Figure 5. If an emission standard is set to the level e^o, the pollution right of e^o belongs to polluters and the pollution right of (e^m-e^o) belongs to the recipients (Figure 5). No wealth transfer transpires between the polluters and the recipients.

Table 1 shows the initial assignments of pollution rights under different policies, as explained in this section. After the compensation of p^oe^o (when recipients have pollution rights) or of $p^o(e^m-e^o)$ (when polluters have pollution rights), all the policies lead to the same result, namely that polluters have the pollution right of e_o and pollution recipients have the pollution rights of (e_m-e_o).

Table 1. Property right structure of alternative regulatory options.

Regulatory Alternatives	Initial distribution of pollution rights		Compensation	Distribution of pollution rights after compensation	
	Pollution right of e^o	Pollution right of (e^m-e^o)		Pollution right of e^o	Pollution right of (e^m-e^o)
Coasean property rights assignment to polluters	Polluter	Polluter	$p^o(e^m-e^o)$ (Max.)	Polluter	Recipient
Coasean property rights assignment to recipients	Recipient	Recipient	p^oe^o (Min.)		
Tradable emission permits of e^o (grandfathering)	Polluter	Recipient	-		
Tradable emission permits of e^o (auction)	Recipient	Recipient	p^oe^o		
Emission charge of p^o	Recipient	Recipient	p^oe^o		
Emission subsidy of p^o	Polluter	Polluter	$p^o(e^m-e^o)$		
Emission standard of e^o	Polluter	Recipient	-		

The property right structures resulting from different regulatory policies have some important implications regarding the selection of policy instruments for the regulation of air pollution, and possibly other types of pollution.

First, if the polluter-pay-principle is strictly adhered to, emissions charges and tradable emission permits with auction are preferred. By implementing these policies, polluters are assigned no pollution rights, and must pay the entire price for any amount of pollution.

Second, the political acceptability of policy by polluters and recipients (and environmental groups) also depends on the distribution of pollution rights. The division of pollution rights into e^o and (e^m-e^o) would be desirable in terms of acceptability to both parties. Policies in which all pollution rights are assigned to either polluters or recipients will be difficult to accept for the other party, who has no rights. Therefore, emission standards and tradable emission permits by grandfathering are more likely to be accepted by both parties. In order to increase the acceptability of emission charges/subsidies and tradable emission permits by auction, a mix of pollution rights is required. For example, in the case of emissions charges, an exemption up to e^o may be necessary in order for the polluters to accept such a policy. Similarly, tradable emission permits with auction allocation may be implemented for a small portion of emission to be accepted by polluters. Additionally, the redistribution of some portion of auction revenues into polluters is another alternative increasing the acceptability of polluters.

Third, the scopes of property rights vary in each policy case. In particular, the existence of residual rights and exchange rights significantly affects the incentive intensity. With the exception of emission standards, all other regulatory policies allow polluters residual rights. That is, polluters can benefit by lowering their emissions. This is a basis for the general assertion of environmental economics textbooks that direct regulations, such as emission standards, are less efficient than policies predicated on economic incentives. In the case of Coasean property assignment, once compensation is agreed on between two parties, there are no additional incentives to reduce emissions further to below the agreed-upon level.

Fourth, the definition of pollution rights requires transaction costs, including the information costs and negotiation costs of defining and allocating pollution rights and monitoring costs after assignment. In selecting policy instruments, transaction costs should be seriously considered. The next section deals with transaction costs in detail, focusing in particular on the transaction costs of tradable emission permits. Table 2 summarizes the attributes of each policy option[1].

Table 2. Key attributes of alternative regulatory options.

Alternatives	Polluter-Pay-Principle	Acceptability		Incentive intensity	Transaction cost	
		polluter	Recipient		Without CMS/eTS*	With CMS/eTS
Coasean property rights assignment to polluters	-	++	-	+	-	-
Coasean property rights assignment to recipients	++	-	++	+	-	-
Tradable emission permits of e^o (grandfathering)	+	+	+	++	-	+
Tradable emission permits of e^o (auction)	++	-	++	++	+	++
Emission charge of p^o	++	-	++	++	+	++
Emission subsidy of p^o	-	++	-	++	+	++
Emission standard of e^o	+	+	+	-	+	++

++: very high or desirable (that is, in case of transaction cost '++' means that cost is very low)
+ : moderate - : low or not desirable
*: CMS: Continuous Monitoring System, eTS: e-Trade System of emission permits

[1] Evaluation of transaction costs for each policy instrument is explained later in this paper.

TRANSACTION COSTS OF ALTERNATIVE AIR POLLUTION REGULATION POLICIES

Williamson (1985) previously asserted that governance structures such as market, hierarchy, or hybrid governance are determined by transaction costs, which vary according to the attributes of the transaction. According to the propositions suggested by Williamson, market governance is the most efficient framework for all standardized transactions, regardless of the frequency. Trilateral governance is required for occasional, nonstandardized transactions. Bilateral or unified governance structures are the most efficient for recurring and nonstandardized transactions.

The transaction costs analysis developed by Williamson has been extended to encompass governance structures for public sector transactions, the types of which can be classified into the following: procurement, redistributional, regulatory, sovereign, judicial, and infrastructure types (e.g. Dixit, 1996; North, 1990b; Williamson, 1999). Among the six types of public sector transactions, this paper addresses regulatory governance. It compares transaction costs of a variety of governance structures for the regulation of air pollution, which are discussed in section 2: emission standards, emission charges and--most notably--tradable emission permits. Technology standards are added as one of the regulatory alternatives discussed in this section.

Transaction costs can be classified into *ex ante* costs and *ex post* costs of transactions (Williamson, 1985). In the case of regulation, *ex ante* costs include information and negotiation costs prior to the implementation of regulation, and the *ex post* costs include the costs of monitoring, enforcement, and dispute resolution after implementation (North, 1990a; Williamson, 1985). Table 3 summarizes the types of transaction costs for each policy instrument. Table 3 divides the transaction costs into the *ex ante* cost and *ex post* cost, as well as into information/monitoring and coordination costs..

Table 3. Types of transaction costs of alternative regulatory options.

Alternatives	Ex ante transaction cost		Ex post transaction cost	
	Information cost	Coordination cost	Monitoring cost	Coordination cost
Coasean property rights assignment	- prior information to assign pollution rights	- negotiation between two parties	- monitoring emissions	- governing disputes
Tradable emission permits	- prior information to assign permits	- negotiation on permits assignment - set-up of auction	- monitoring emissions	- transaction of permits - enforcement
Emission charge/subsidy	- prior information to set levels of charge/subsidy	- negotiation on emission charge/subsidy	- monitoring emissions	-financial administration - enforcement
Emission standard	- prior information to set emission standards	- negotiation on emission standards	- monitoring emissions	- enforcement
Technology standard	- prior information to set technology standards	- negotiation on technology standards	- monitoring technology	- enforcement

Generally, the transaction costs of Coasean property rights assignment are quite high, particularly when there exist multiple polluters or pollution recipients. Negotiation between two parties (*ex ante* cost) is quite costly in reaching an agreement, and the governance of the agreement (*ex post* cost) will also be quite costly without government regulation. Therefore, Table 4 demonstrates that the transaction costs of Coasean property rights assignment are relatively higher than those of other regulatory options.

The *ex ante* costs of tradable emission permits include information cost and negotiation cost for the allocation of emission permits. Unless allocation is achieved by auction, it is conducted on the basis of past emissions of individual sources or the predetermined emission ratios of each source group.

Therefore, regulatory authorities require detailed information of the emission records of each source. This is similar to the case of emission standards. In the case of technology standards, regulatory agencies require information regarding the best and most updated technology available. In terms of *ex ante* transaction costs, emission charges require less information prior to implementation than other policy instruments.

The ex post transaction costs of emission charges and tradable emission permits are quite high because regulatory agencies require precise monitoring of emissions from individual sources. Additionally, transaction costs between permit traders should be added for the ex post transaction costs of tradable emission permits. Meanwhile, in the case of emission standards, agencies need only to monitor whether emissions exceed the pre-determined amounts. The ex post transaction costs of technology standards are relatively low because it is less costly to monitor the installation of the best available technology than to monitor the amount of emissions.

To compare the *ex ante* and *ex post* costs in totality, the transaction cost of tradable emission permits in particular, with the allocation of permits by grandfathering, is generally higher than that of alternative policy instruments. Table 4 compares the transaction costs of tradable emission permits, emission charges, emission standards, and technology standards.

Table 4. Transaction costs of alternative regulatory options.

Alternatives	Ex ante transaction cost		Ex post transaction cost		Transaction cost (total)
	Information cost	Coordination cost	Monitoring cost	Coordination cost	
Coasean property rights assignment	-	-	+	+	-
Tradable emission permits (grandfathering)	-	-	-	-	-
Tradable emission permits (auction)	++	+	-	-	+
Emission charge/subsidy	++	+	-	-	+
Emission standard	-	+	+	++	+
Technology standard	+	+	+	++	++

++: desirable (cost is very low) + : moderate - : not desirable (cost is very high)

Table 5. Transaction costs of alternative regulatory options under CMS and eTS.

Alternatives	Ex ante transaction cost		Ex post transaction cost		Transaction cost (total)
	Information cost	Coordination cost	Monitoring cost	Coordination cost	
Coasean property rights assignment	-	-	+	+	-
Tradable emission permits (grandfathering)	+	-	++	+	+
Tradable emission permits (auction)	++	+	++	+	++
Emission charge/subsidy	++	+	++	-	++
Emission standard	++	+	++	++	++
Technology standard	+	+	+	++	++

++: desirable (cost is very low) + : moderate - : not desirable (cost is very high)

However, the transaction costs of each policy instrument are extremely dependent on the current state of technology. For example, monitoring costs can be lowered significantly if automatic continuous monitoring systems (CMS), by which a regulatory agency can precisely monitor the amounts of emissions generated by individual sources in real time, were in wider use. In fact, the use of CMS by large facilities is increasing under conditions of tradable emission permits such as the RECLAIM (Regional Clean Air Incentives Market) of California (South Coast Air Quality Management District, 2007). Additionally, transaction costs between permits traders are also reduced significantly with the installation of an online-based transaction system (eTS), which is clearly becoming an essential component of tradable emission permits. Table 5 compares the transaction costs of alternative regulatory policies, assuming that the latest monitoring technologies such as CMS are fully installed and the permit transactions are systematically managed and recorded by TMS.

CONCLUSION: CHOICE OF POLICY INSTRUMENTS FOR THE REGULATION OF AIR POLLUTION

Summing up the discussions provided in sections 2 and 3, the following principles can be proposed as a guide for selecting policy instruments for the regulation of air pollution. In fact, this suggestion can be extended to other pollution issues.

First, if the polluter-pay-principle is strictly adhered to, emission charges and tradable emission permits by auction are preferred. By implementing these policies, polluters are assigned no pollution rights, and are compelled to pay the entire price for any amount of pollution. Second, the political acceptability of policy by polluters and recipients (and environmental groups) is dependent on the distribution of pollution rights. Emission standards and tradable emission permits with grandfathering are more likely to be accepted by both parties. To increase the acceptability of emission charges/subsidies and tradable emission permits by auction, a mix of pollution rights is required. For example, in the case of emission charges, an exemption up to e^o may be necessary for the polluters to accept such a policy. Similarly, tradable emission permits with auction allocation may be implemented for a small portion of emissions to be accepted by polluters. Additionally, the redistribution of some portion of auction revenues into polluters is another alternative by which the acceptability of these policies to polluters can be increased. Third, direct regulations, such as emission standards, are less efficient than policies predicated on economic incentives, because the incentive intensity is substantially lower than that of alternative policy instruments. It does not allow for residual rights nor for the right to exchange or trade pollution rights. Fourth, in selecting policy instruments, the transaction costs should be taken seriously into consideration. The transaction costs of tradable emission permits are relatively higher than other alternative regulations. In particular, the allocation of permits by grandfathering results in high transaction costs in terms of the *ex ante* cost as well as the *ex post* cost. However, the transaction costs of tradable emission permits can be lowered significantly by installing the latest technology monitoring emissions, such as CMS or online-based transaction systems, which are essential elements in the success of tradable permits for the emissions of local air pollution, including NOx and SOx.

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