Transaction Costs, Economic Instruments and Environmental Policies

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INTRODUCTION

There has been a shift in environmental policy tools from moral suasion and direct regulation to market based instruments since these instruments are generally more flexible, efficient and cost-effective in achieving environmental policy objectives (Tietenberg, 1991). Yet, the actual efficiency gains from economic instruments have been found to be lower than their theoretical potential (Hahn, 1989, Hahn and Stavins, 1992). Among the potential reasons for economic instruments not functioning properly is the influence of transacttion costs (Kohn, 1991, Stavins, 1995, Smith and Tomasi, 1995, McCann and Easter, 1998).

The concept of transaction costs has been associated with Coase (1992), who broadly defines these costs as the resources spent on successful consummation of an exchange. The concept has been used largely to explain organizational behavior of industries, firms and markets. Within the environmental policy literature, transaction costs has been defined much more narrowly and in terms of two sub-components. One component involves the costs of policy design, administrative costs, and enforcement. This tradition formalized in Polinsky and Shavell, (1982) has been referred to by Griffin and Bromely (1982) as policy transaction costs and by Thompson (1999) as institutional transaction costs. The other component considers search, bargaining, monitoring and enforcement costs. These market transaction costs have been formally modeled by Stavins (1995) in an analysis of tradable permit markets for pollutants and more recently by Montero (1997), Vatn (1998), and Ganghadaran, (1999). The gap in the literature is in unifying the analysis of the different kinds of transaction costs for economic instruments and analyzing their impact on social welfare.

The purpose of this paper is to examine the implications for environmental policy choice from an analytical model that incorporates a complete definition of transaction costs of economic instruments. In assessing the social welfare impacts of economic instrument selection, the transaction costs of both the regulator and the firm in successfully executing the policy are accounted for. The paper begins with discussion of the standard model without transaction costs for determining the optimal level of pollution and how the regulator is indifferent to taxes or permits under such assumptions. The next section of the paper describes transaction costs and how the concepts apply to the application of economic instruments for environmental policy purposes. Policy and marketing transaction costs along with their arguments are defined for both the polluting firm and the regulator. The final section of the paper incorporates these transaction costs to select for the optimal policy instrument. The results show that emission levels change with the characteristics of the instrument and from the standard model approach.

ENVIRONMENTAL POLICY CHOICE WITHOUT TRANSACTION COSTS

The objective in environmental policy design is to achieve a given level of ambient air or water quality at least cost (Kelman, 1981). The standard model presented below demonstrates that either with Pigouvian taxes or tradable permits socially optimal pollution control is achievable. In this model, that follows that of Polinsky and Shavell (1982), we assume perfectly competitive input and output markets. A representative firm's production function given by $f(X,e)$. Inputs are represented by vector X and e is the level of emission (unit weight/per period) in the production process. The external harm produce by emission is characterized by the surplus of emission produced by the firm above its emission constraint e^*. The emission constraint is determined by the regulator and the damage function, $D(e\text{-}e^*)$, is assumed to be linear. Firms sell their output at price P and inputs price vector is given by vector W. The social planner maximizes the social welfare subjected to the firm's meeting the emission constraint.

(1) $$\text{Max}_e \, \text{W} = P\, f\,(X,e) - W\,X - \mu\,(e - e^*).$$

where μ is the Lagrangian multiplier for the emission constraint for the firm.

The first order condition:

(2) $$P\, f_e\,(X,e) - \mu = 0$$

gives the standard result the optimal level of pollutant is where the marginal damage from an additional emission is equal to the firm's marginal gain from emission. This socially optimal emission level can be achieved either by a Pigouvian tax equal to μ or by restricting total emissions in a permit market for which the equilibrium permit price will also equal μ.

There are two qualifications to make about this socially optimal pollution level and the capability of economic instruments to achieve this level. As Vatn, 1998 noted, the standard model above does not account for transaction costs associated with measuring emissions and implementing the solution arrived in the first order condition. In deriving the marginal conditions for the efficient intensity of pollution control (2), it is assumed that the transaction costs of implementing the solution is zero (Kohn, 1991). Furthermore, this formulation does not provide any explanation of the suitability of a given economic instrument over another. Each policy instrument corresponds to different resource requirements for its successful execution. Therefore, to incorporate resource requirements for the different economic instruments, we have to adopt a social welfare perspective in instrument choice.

ECONOMIC INSTRUMENTS AND TRANSACTION COSTS

Transaction costs economics as initiated by Coase assesses the relative merits of alternative organizational arrangements for trade by focusing on the nature and size of barriers between parties that reduce potential gains from trade. The choice among alternative organizational arrangements turns on a comparison of the costs of transacting under each (Masten *et al*, 1991). Those costs depend on aspects such as the frequency, uncertainty and asset specificity of a given transaction (Williamson, 1985). The appropriate organizational mode for a transaction (hierarchically or in markets or by regulatory bodies) will be the one that brings the intended results of the transaction at lowest cost.

The successful execution of an economic instrument for environmental purposes invovles the facilitation of a transaction. The transaction is either between polluting firms and the regulator (Pigouvian taxes) or between polluting firms with the assistance of the regulator (tradable permits). However, these transactions do not consist of voluntary exchange typical in market transactions but instead invariably involve some kind of coercion. Voluntary market transaction that internalize Pareto relevant externalities is, as Baumol and Oates, 1988 noted, only valid for a small number cases and therefore they note for such cases the Coasian property-right approach may well be the most sensible way to control the externality.

The costs of administrative involvement with coercion inevitable with pollution problems have been termed by both Griffin and Bromley (1982) and Thompson (1999) as “transaction costs” without clearly explaining the underlying transaction. These administrative costs are largely borne by the regulator executing the program and firms are passive followers but firms will bear the burden of some costs of monitoring and reporting their emissions under any policy approach to pollution control (Seskin *et al*, 1982). As with Pigouvian taxes, resources will be spent by both firms and the regulator to affect the intended transaction. Rather than assume no costs for the regulatory body in a tradable permits policy and only firms are involved in the exchange of tradable permits, Hahn (1990) notes that the regulatory system is more complicated with emission trading.

In developing a unifying theory to accommodate the forms of transaction costs discussed in the environmental policy literature, we categorized transaction costs into two broad groups; policy transaction cost and market transaction costs. Both firms and the regulator incur these costs and they are discussed below.

Policy and Market Transaction Costs for the Firm R_F $(T(m_f, D_f, L_f), M(I_f, S_f, N_f, E_f))$

The transaction costs associated with a given environmental policy for the firm, R_F , is function of two types of costs; policy transaction costs T, and market transaction costs M.

Policy Transaction Costs for the Firm $T(m_f, D_f, L_f)$

Policy transaction costs for the firm are the firm's incremental administrative costs in complying with the economic instrument. These are borne in the form of monitoring costs, time spent completing forms, and the expenses of resolving disputes over tax liability (Polinsky and Shavell, 1982). Following Polinsky and Shavell, 1982, we formulate policy transaction cost of firm, $T(m_f, D_f, L_f)$, as a function of three arguments. The argument m_f is the monitoring costs by firms when they have to pay emission taxes. To determine its tax liability or to contradict any tax claims of the regulator, the firm has to measure its emission level. The argument D_f is desk work and filling forms. The last factor, L_f is the cost involved in liability resolving. For example, if a firm disputes the regulator's tax claim, it has to follow administrative procedures and subsequently incur costs.

Market Transaction Costs for the Firm $M(I_f, S_f, N_f, E_f)$

Following Stavins, 1995, we formulate market transaction cost of firms, *M*, as a function of four arguments; I_f = information cost for the firm, S_f = search cost for the firm for trade partners, N_f= negotiation costs, and E_f = enforcing the negotiated terms. These costs items are widely known in the literature and no further elaboration is provided here at this time.

Policy and Market Transaction Costs for Regulator $R_G\ (T(e_g, I_g, P_g\ ID_g), M(e_g, M_g, A_g))$

The regulator also faces two types of transaction costs.

Policy Transaction Costs for the Regulator $T(e_g, I_g, P_{g\ Idg})$

Policy transaction costs for the regulator are the transaction costs most frequently referred to in the environmental policy literature (i.e. Griffin and Bromley, 1982). We follow the Thompson (1998) specification so that the regulator's policy transaction costs, $T(e_g, I_g, ID_g, P_g)$, are a function of e_g = enactment costs of the policy, I_g = implementation cost of the policy, ID_g = inducement and detection costs of compliance, and P_g = prosecution cost of non-compliant firms. McCann and Easter (1998) have estimated these costs for different policy options for phosphorus pollution control in Minnesota.

Market Transaction Costs for the Regulator $M(e_g, M_g, A_g)$

Market transaction costs for the regulator are not considered in the literature, however, as Dales (1968) notes, tradable permits are basically administrative tools. Therefore, they incur some costs to the regulator. Hahn (1990) outlines the extent of regulatory involvement in implementing tradable emission rights. The market transaction costs for the regulator in implementing an environmental policy, $M(e_g, M_g, A_g)$, is formulated as a function of e_g = enactment costs of the tradable permits, M_g = monitoring cost for the regulator, A_g = administration costs for the continuation of tradable permit system.

ENVIRONMENTAL POLICY CHOICE WITH TRANSACTION COSTS

The standard model presented earlier is now extended to include transaction costs as an economic instrument selection criterion. The firms' emission function, $e(a,\ R_F\,(T(m_f, D_f, L_f), M(I_f, S_f, N_f, E_f))$, depends on abatement costs a, and transaction costs of the economic instrument R_F. In this specification we assume $e(.)$ is strictly concave function in R_F and a. We also assume $R_F\,(.)$ is strictly concave function in both its argument. We further assume cross partials of R_F, i.e., $\partial^2 R_F / \partial T\, \partial M$ and $\partial^2 R_F / \partial M\, \partial T$ are negative. Given the emission function and the transaction cost functions for the firm and regulator presented above, the social planner's objective to maximize social welfare with emission control in the presence of transaction costs can now be formally stated as;

(3) $\mathrm{Max}_{T,\,M}\ \mathrm{W} = Pf(X, e(a, R_F(T(m_f, D_f, L_f), M(I_f, S_f, N_f, E_f))) - W X - R_G\,(T(e_g, I_g, P_g\, ID_g), M(e_g, M_g, A_g)) - \mu(\ e(a, R_F\,(T(m_f, D_f, L_f), M(I_f, S_f, N_f, E_f) - \mathrm{e}^*)$.

First order conditions for above maximization is (we suppress the arguments in both R_F and R_G) with respect to T (Transaction cost of Pigouvian taxes) and M (Transaction costs in tradable permits).

(4) $$\frac{\partial W}{\partial T} = \left[P\,\frac{\partial f}{\partial e}\,\frac{\partial e}{\partial R_F}\,\frac{\partial R_F}{\partial T} \right] - \frac{\partial R_G}{\partial T} - \left[\mu\,\frac{\partial e}{\partial R_F}\,\frac{\partial R_F}{\partial T} \right] = 0$$

(5) $$\frac{\partial W}{\partial M} = \left[P \frac{\partial f}{\partial e} \frac{\partial e}{\partial R_F} \frac{\partial R_F}{\partial M} \right] - \frac{\partial R_G}{\partial M} - \left[\mu \frac{\partial e}{\partial R_F} \frac{\partial R_F}{\partial M} \right] = 0$$

Rearranging (4) and (5) we can get;

(6) $$\frac{\partial W}{\partial T} = \left[(P \frac{\partial f}{\partial e} - \mu) \frac{\partial e}{\partial R_F} \frac{\partial R_F}{\partial T} \right] - \frac{\partial R_G}{\partial T} = 0$$

(6') $$\frac{\partial W}{\partial M} = \left[(P \frac{\partial f}{\partial e} - \mu) \frac{\partial e}{\partial R_F} \frac{\partial R_F}{\partial M} \right] - \frac{\partial R_G}{\partial M} = 0$$

The resultant social optimum with transaction costs is different from standard model in two important dimensions. Firstly, our choice variable in the standard model was emission level *e*. However, the choice variables for the second model are policy transaction costs (*T*) and market transaction costs (*M*). Secondly, if transaction costs vary among the instruments, the optimal emission level for each policy will be different. However, we can compare the socially optimum emission levels in the two models and infer the impact of incorporation of transaction costs on the socially optimal emission level. Recall we assumed that both R_F and R_G (T, M) are increasing functions of *T* and *M*. We also assumed $e(a, R_F(T, M))$ is an increasing function of R_F. Therefore, from (6) or (6') we can infer that $\left[(P \frac{\partial f}{\partial e} - \mu) \right] > 0.$ Thus, the socially optimal emission level with transaction costs is lower than under the standard model. We cannot determine the size of this departure from the standard model. However, the important result of the analyses is that incorporation of transaction costs makes optimal level of pollution varied among economic instruments.

The welfare impacts of having either type of economic instrument could be mathematically demonstrated by taking the total derivative of equation (4) with respect to *T* and *M*. We can then model social indifference curves in *T* and *M* space indicating the combination of policy and market transaction costs with the same level of social welfare. Then for this social indifference map we can introduce an emission constraint as a budget constraint. The total derivative of (4) with respect to *T* and *M* is

(7) $$dW = \left[P \frac{\partial f}{\partial e} \frac{\partial e}{\partial R_F} \frac{\partial R_F}{\partial T} - \mu \frac{\partial e}{\partial R_F} \frac{\partial R_F}{\partial T} - \frac{\partial R_G}{\partial T} \right] dT + \left[P \frac{\partial f}{\partial e} \frac{\partial e}{\partial R_F} \frac{\partial R_F}{\partial M} - \mu \frac{\partial e}{\partial R_F} \frac{\partial R_F}{\partial M} - \frac{\partial R_G}{\partial M} \right] dM$$

Social welfare indifference curves in *T* and *M* dimension are given by $dW=0$ for a given level of *W*. The social welfare indifference curves given by dT/dM are negatively sloped, i.e., $dT/dM < 0$[1]. The curvature of welfare indifference curve could be ascertained with signing d^2T/dM^2. We define

$A = \left[P \frac{\partial f}{\partial e} \frac{\partial e}{\partial R_F} \frac{\partial R_F}{\partial T} - \mu \frac{\partial e}{\partial R_F} \frac{\partial R_F}{\partial T} - \frac{\partial R_G}{\partial T} \right]$ and $B = \left[P \frac{\partial f}{\partial e} \frac{\partial e}{\partial R_F} \frac{\partial R_F}{\partial M} - \mu \frac{\partial e}{\partial R_F} \frac{\partial R_F}{\partial M} - \frac{\partial R_G}{\partial M} \right]$. Therefore,

$d^2T/dM^2 = -[(A)(\partial B/\partial M) + (B)(\partial A/\partial M)]/(A)^2$. We can derive $\partial B/\partial M$ and $\partial A/\partial M$ as follows;

$\partial B/\partial M = [P(\partial^2 e/\partial^2 R_F . \partial^2 R_F / \partial T\, \partial M) - \mu(\partial^2 e/\partial R_F{}^{2.} . \partial R_F{}^{2.} / \partial T\, \partial M) - (\partial^2 R_G / \partial T\, \partial M)]$

$\partial A/\partial M = [P(\partial^2 e/\partial^2 R_F . \partial^2 R_F / \partial^2 M) - \mu(\partial^2 e/\partial R_F{}^{2.} . \partial R_F{}^{2.} / \partial^2 M) - (\partial^2 R_G / \partial^2 M)]$

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[1]. We assume that implementing economic instruments with incurring transaction costs provide social benefits. Therefore, the terms $\left[P \frac{\partial f}{\partial e} \frac{\partial e}{\partial R_F} \frac{\partial R_F}{\partial T} - \mu \frac{\partial e}{\partial R_F} \frac{\partial R_F}{\partial T} - \frac{\partial R_G}{\partial T} \right]$ and $\left[P \frac{\partial f}{\partial e} \frac{\partial e}{\partial R_F} \frac{\partial R_F}{\partial M} - \mu \frac{\partial e}{\partial R_F} \frac{\partial R_F}{\partial M} - \frac{\partial R_G}{\partial M} \right]$ are assumed to be positive.

The cross partial of R_F (.) is assumed to be zero. We assume W is a strictly concave function[2] in both M and T, therefore, $\partial A/\partial M > 0$. Taking this information together, we have $d^2T/dM^2 < 0$, indicating downward sloping concave welfare indifference curves in T and M space.

Similarly emission constraint could also be portrayed as iso-emission curves for a given level of emission. An rmission constraint is given by $e(a, R_F\ (T(m_f, D_f, L_f), M(I_f, S_f, N_f, E_f)) = e^*$ in the above model. Iso-emission lines could be generated for different level of e^* in T and M space. Total derivative of emission constraint with respect to T and M gives;

(8) $$de^* = \left[\frac{\partial e}{\partial R_F}\frac{\partial R_F}{\partial T}\right]dT + \left[\frac{\partial e}{\partial R_F}\frac{\partial R_F}{\partial M}\right]dM$$

The slope of the iso-emission curve dT/dM is negative (given the characteristics of e(.) and R_F(.)). Defining

$$C = \left[\frac{\partial e}{\partial R_F}\frac{\partial R_F}{\partial T}\right] \quad \text{and} \quad D = \left[\frac{\partial e}{\partial R_F}\frac{\partial R_F}{\partial M}\right]. \quad \text{then}$$

$d^2T/dM^2 = -[(C)(\partial D/\partial M) + (D)(\partial C/\partial M)]/(D)^2$ for which

$\partial C/\partial M = (\partial^2 e/\partial^2 R_F . \partial^2 R_F / \partial T\ \partial M)$ and $\partial D/\partial M = (\partial^2 e/\partial R_F{}^{2.} . \partial R_F{}^{2.}/\partial^2 M)$.

Using the same assumptions about zero cross partials of R_F (.) and with the assumption that e(.) is strictly concave in M, we have iso-emission lines that are concave and downward sloping in T, M space.

We can depict both welfare indifference curves and iso-emission lines in T and M space.

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[2]. As the transaction costs of an economic instrument's increases, social welfare for a given level of emission control will be decreased at increasing rate.

Higher welfare levels are with the indifference curves that are closer to the origin (since welfare is decreasing in both *T* and *M*). Social welfare will be maximized moving to the lowest welfare indifference curve subject to a given level of emission constraint. We can have three possible situations depending on the relative sizes of the curvatures of iso-emission line and welfare indifference curve.

(1). Equal curvature for the both curves

This is a very unlikely situation. However, in such a situation both instruments are capable of achieving same level of social welfare subjected to the chosen emission constraint. This situation is not interested in environmental policy formulation.

(2). A tangency between iso-emission and welfare indifference curve.

This is the theoretical optimum if substitution between *T* and *M* is possible but we cannot substitute at the margin between *T* and *M*. Also when such a tangency occurs, moving to a corner solution across the relevant welfare indifference curves (in selecting one instrument) does not differentiate across the instruments.

(3). Crossing of two curves.

Whenever the two curves cross, a corner solution results and the optimal instrument selected will depend on two characteristics; relative steepness of the curves and the chosen emission constraint. What determines the relative steepness of the two curves? As we have seen in determining the slope of both curves, the functions such $e(.)$ $R_F(.)$ and $R_G(.)$ and their specification play important roles. It must be noted that the recent literature in economic instrument choice has focused on the requirement of characterizing the above functions. McCann and Easter (1998) try to estimate the policy transaction costs with policies such as extension services, and input taxes for controlling phosphorus pollution in the Minnesota River. Thompson (1999) compares institutional transaction costs with a non-tradable permit system and an effluent charge system to control pollution from textile mills.

CONCLUSION

This study has attempted to distinguish the alternative forms of transaction costs referred to the environmental policy literature and to bring these transaction costs into a unified theory. The optimal choice of economic instrument between Pigouvian taxes and tradable permits is shown to depend on the level of transaction costs as opposed to the standard model where both emission taxes and permits are first best policies to achieve a level of emissions. It is demonstrated that inclusion of transaction costs decrease the socially optimal emission level as compared to the standard model. Instrument selection is affected by the functional specification for instrument costs for both firm and regulator level. Depending on the nature of these costs optimal economic instruments will be different.

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