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Transactions Costs and Point-Nonpoint Source Water Pollution Trading

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Water quality trading is being promoted by the U.S. EPA and explored by several states as a means for achieving water quality goals, especially within the context of EPA's Total Maximum Daily Load (TMDL) program. Water quality trading is fundamentally a decentralized mechanism for allocating, as required by the TMDL program, pollution loads among alternative sources consistent with an overall pollution load target. The primary objective of trading is to achieve water quality goals cost-effectively by allowing pollution sources with high control costs to meet their regulatory obligations by purchasing environmentally equivalent pollution reductions from pollution sources with lower costs.

A major challenge to the success of water quality trading is to control agricultural nonpoint sources. Agricultural nonpoint sources are the leading cause of remaining water quality problems and must be controlled if water quality objectives are to be achieved in many watersheds. Yet, the very character of nonpoint pollution, unobservable and stochastic discharges, greatly complicates the design of markets. Economic research on the design of markets with nonpoint sources has focused largely on two questions. One is the appropriate choice of the "commodity" for nonpoint trades. Major options considered have been modeled emissions and inputs that determine nonpoint loads. A second question is the appropriate design of trading ratios for trades between point and nonpoint sources to account for their being, due primarily to the relative uncertainty about nonpoint loads, imperfect substitutes.

This research explores the implications of transactions costs for the design and performance of water quality trading systems including point and agricultural nonpoint sources. Although the impacts of transactions costs on tradable permit markets with point sources have received significant attention, there is little research on transactions costs in point-nonpoint source (PS/NPS) pollution trading. Like other trading systems, transactions costs in PS/NPS pollution trading can act as barriers to trade, suppressing the number of trades to a level below that could have been obtained in the costless trade case. This is because transactions costs would expect to increase the permit prices for point and nonpoint source pollution. Procedures to address risk in trades with nonpoint sources may imply high transactions costs that diminish the potential gains from trading.

The article contains three remaining sections. First, a discussion on the nature of transactions costs and a brief literature review on transactions costs in water pollution trading will be presented. Second, a model on point source emissions for modeled nonpoint source runoff trading program in a TDML context with transactions costs will be constructed with a purpose to explore the implications of transactions costs on the trading design and performance. Third, concluding comments and suggestions for further research will close the discussion.

Transactions Costs in Pollution Trading

Studies on the design of PS/NPS trading system have tackled important issues including the optimal bases for trading, trading ratios (Letson 1992; Malik et al. 1993; Horan et al. 2001; Horan et al. 2002; Shortle and Horan 2001; Horan and Shortle 2005) and asymmetric nature of information in the trading programs (Johansson 2002). They, however, neglected to provide a formal analysis of the implications of transactions costs for the structure of trades, the efficiency, and the optimal design of PS/NPS trading markets. Yet, features of the agricultural nonpoint problem suggest that transaction costs may be a significant factor (McCann and Easter 1999; Shortle et al. 1998; Shortle and Horan 2001).

Stavins (1995) defined transactions costs as inputs of resources or the difference between the buying and selling price of a commodity. When there are transfers of any property right, parties in the exchanges have to find one another, communicate and exchange information, which incurs transactions costs. The categories of transactions costs include search costs, negotiation costs, approval costs, monitoring costs, enforcement costs and insurance costs (Dudek and Wiener 1996 cited in Woerdman 2001). Transactions costs in PS/NPS trading consist of similar cost components as in any other permit trading programs. In this article, however, transactions costs can be thought of as some kind of economic impediments that sources incur when trading permits with each other. There will be separate transactions costs in exchanges of NPS and PS permits. Transactions costs will be functions of the number of permits sold or purchased of each permit type.

There have been several theoretical and empirical studies on the impacts of transactions costs on the outcome of tradable permits markets. In Stavins’ paper (1995), transactions costs representing direct financial costs of brokerage services increase abatement costs and decrease the number of trades in point emission permit markets for all the functional forms of transactions costs assumed (fixed cost only, constant marginal transactions costs

(MTC), increasing MTC and decreasing MTC). He, therefore, questions the exaggeration of the advantage due to their relative cost-effectiveness of tradable permit systems over the conventional command and control policies of pollution control. Montero (1997) extends Stavins' (1995) by developing theoretical and numerical models that include uncertainty in trade approval and transactions costs, at the same time, allowing for the marginal control cost curves to be discontinuous. He finds qualitative similar results to those presented in Stavins' (1995). However, the numerical model for a hypothetical NO_x trading program shows that marketable permit system is still cost-effective even at high level of transactions costs and uncertainty. When the initial allocation of permits is close to the least-cost equilibrium, there is minimal reduction of the overall welfare.

Cason and Gangadharan have done a number of empirical research on transactions costs in tradable permit markets. Gangadharan (2000) uses an econometric approach to show that some transactions costs variables can explain why a significant number of facilities do not trade in the Regional Clean Air Incentives Market (RECLAIM) in Los Angeles. The author suggests that regulators must design programs that facilitate the evolution of market, encouraging participation in order to obtain the projected cost savings from permit markets. Cason and Gangadharan (2003) conducted an experimental study to investigate how transactions costs interact with initial permit allocations to determine the cost-effectiveness of emissions abatement. The experiments provide a formal test for the theoretical hypotheses proposed in Stavins (1995).

Nagurney and Dhanda (2000) model multi-product, multi-pollutant oligopolistic firms engaging in competitive markets of ambient-based pollution permits in the presence of transactions costs. The authors include both uniformly and non-uniformly mixed assimilative pollutants in their model of ambient-based pollution permit system. The model allows for product market imperfection, uniformly and non-uniformly mixed assimilative pollutants trading and transactions costs but it has not dealt with trading in PS/NPS pollution in the presence of transactions costs. The ambient concentration in the model is formed by uniformly and non-uniformly mixed assimilative pollutants of point source emissions. The uncertainty and unobservability in the measure of nonpoint source emissions have not been accounted for in this paper.

It is interesting, however, to note that most of these studies concern with air rather than water pollution trading and, if water trading is considered, the focus is point source emissions rather than nonpoint source pollution. Transactions costs and nonpoint source water pollution trading, therefore, remain a much unexplored area of environmental policy research. This article, therefore, seeks to narrow the gap in this area of research. In the next section, a model of point source for modeled nonpoint source trading program in a TMDL context with transactions costs will be constructed. Cap-and-trade is the type of market for the PS/NPS water pollution trading program and transactions costs are explicitly accounted for in both selling and buying exchanges of NPS and PS permits.

Model of PS/NPS Water Pollution Trading with Transactions Costs

A PS/NPS water pollution trading market can be thought of in the context of a river along which there are both point and agricultural nonpoint sources whose emissions contribute to the ambient concentration of the watershed. Point sources produce uniformly mixing emissions, e_k (k=1,…,s), which can be measured with certainty but nonpoint source loadings, r_i (i=1,…,n), are stochastic and unobserved, which will involve uncertainty in their measurement. It is assumed that there is only one receptor area. A depiction of such a watershed can been seen in figure 1.

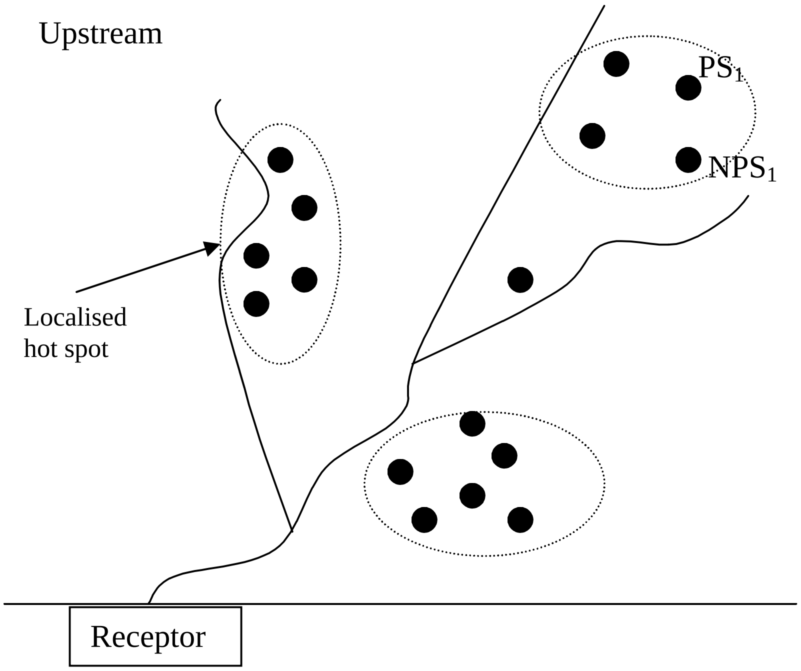

Figure 1. An illustration of a watershed with point and nonpoint sources

First-best market design

The water quality authority wants to minimize the cost of achieving a TMDL-type target of the form

$$(1) \qquad \sum_i r_i + \sum_j e_j \leq T + M$$

where r is nps runoff, e is ps emissions, T is the target, and M is the Margin of Error.

Assuming that M is selected according to the probability of violation which is considered acceptable, then this constraint can be re-expressed as

$$(2) \qquad \Pr ob(\sum_i r_i + \sum_j e_j \leq T) \geq \alpha$$

where α is the minimum probability water quality will accept for achieving the standard. Without knowledge of the joint distribution function for nonpoint emissions, Chebychev inequality can be used to express the environmental target as

$$(3) \qquad \sum_i \mu_i + \sum_j e_j \leq T + (\frac{1}{1-\alpha})^{1/2} (\sum_i \sigma_{ii} + 2\sum_i \sum_{<j} \sigma_{ij})^{1/2}$$

where $\mu_i = E(r_i)$ and $\sigma_{ij} = E(r_i r_j)$. Accordingly, the margin of error is expressed in terms of the variance of total emissions, which depends on the variances and covariances of the nonpoint sources. In other words,

$$M = (\frac{1}{1-\alpha})^{1/2} (\sum_i \sigma_i^2 + 2\sum_i \sum_j \sigma_{ij})^{1/2}$$

Trading

Following the development of US trading programs, trading takes place between mean nonpoint source emission and actual point source emissions. The imperfect substitution between point and nonpoint sources is handled using a trade ratio, t. The ratio would optimally be differentiated, but again consistent with the development of US programs, we take the trade ratio to be uniform for all PS/NPS trades. There are two types of permits, NPS permits, and PS permits. A firm has an endowment of each type, and then can buy or sell within or across types. Let:

r_i^0 = the initial allocation of NPS permits to source i

e_i^0 = the initial allocation of PS permits to source i

br_i = purchases of NPS permits by source i

sr_i = sales of NPS permits by source i

be_i = purchases of PS permits by source i

se_i = sales of PS permits by source i

A firm's PS permit holdings are therefore given by:

(4) $\bar{e}_i = e_i^0 + be_i - se_i$

Similarly, a firm's NPS permit holding are given by

(5) $\bar{r}_i = r_i^0 + br_i - sr_i$

Firms are required to hold sufficient permits to justify the emissions, or modeled runoff levels. For a PS firm, the constraint is

(6) $e_i \leq t\bar{r}_i + \bar{e}_i$

where t is the trade ratio set by the water quality authority to adjust for the imperfect substitution between point and nonpoint sources. The restriction on an NPS firm is

(7) $\mu_i \leq t\bar{r}_i + \bar{e}_i$

where $\mu_i = E(r_i)$ is the modeled nonpoint source loadings. The agricultural runoff and the point source emissions in this model are both considered to be uniformly mixed across all sources.

The water quality authority limits permits such that

(8) $$\sum_i t\mu_i + \sum_k e_k \le Z$$

The market is assumed to be perfectly competitive. In equilibrium, PS permits trade at price p_e and NPS permits trade at price p_r.

NPS Profit Maximization

In the market equilibrium, NPS firm i (for all i) maximizes its profit

$$\hat{\pi}_i^r = \pi_i^r(\mu_i) + p_e(se_i - be_i) + p_r(sr_i - br_i) - TC_s^e(se_i) - TC_b^e(be_i) - TC_s^r(sr_i) - TC_b^r(br_i)$$

subject to (4), (5), and (7), where $TC_z^l(.)$ is the transactions cost of purchasing (z = b) or selling (z = s) permits of type l (l = r or l= e). The firm's Kuhn Tucker Lagrange function, after combing the constraints, is

$$L_r = \hat{\pi}_i^r + \lambda[t(r_i^0 + br_i - sr_i) + (e_i^0 + be_i - se_i) - \mu_i]$$

First order necessary conditions include

(9) $$\frac{\partial L_r}{\partial \mu_i} = \frac{\partial \pi_i^r}{\partial \mu_i} - \lambda_r \le 0\,,\ (\frac{\partial L_r}{\mu_i})\mu_i = 0\,,\ \mu_i \ge 0$$

(10) $$\frac{\partial L_r}{\partial br_i} = -p_r - \frac{\partial TC_b^r}{\partial br_i} + t\lambda_r \le 0\,,\ (\frac{\partial L_r}{\partial br_i})br_i = 0\,,\ br_i \ge 0$$

(11) $$\frac{\partial L_r}{\partial sr_i} = p_r - \frac{\partial TC_s^r}{\partial sr_i} - t\lambda_r \le 0\,,\ (\frac{\partial L_r}{\partial sr_i})sr_i = 0\,,\ sr_i \ge 0$$

(12) $$\frac{\partial L_r}{\partial be_i} = -p_e - \frac{\partial TC_b^e}{\partial be_i} + \lambda_r \le 0\,,\ (\frac{\partial L_r}{\partial be_i})be_i = 0\,,\ be_i \ge 0$$

(13) $$\frac{\partial L_r}{\partial se_i} = p_e - \frac{\partial TC_s^e}{\partial se_i} - \lambda_r \le 0\,,\ (\frac{\partial L_r}{\partial se_i})se_i = 0\,,\ se_i \ge 0$$

We assume (9) is satisfied as an equality, implying that the firm produces. Arbitrage will eliminate opportunities to profit from buying permits simply to sell permits of any given type. Accordingly, in equilibrium a firm will be either buyer or seller of NPS permits, but not both, and will either buy or sell PS permits, but not both. Further if the firm is a buyer of NPS permits, it will not be a seller of PS permits, nor will a firm that is a buyer of PS permits be a seller of NPS permits. Finally, arbitrage will lead to the indifference between purchases or sales of alternative permit types. In equilibrium, several cases can then be defined:

(i) NPS firm buying NPS permits and/or buying PS permits
(ii) NPS firm selling NPS permits and/ or selling PS permits
(iii) PS firm buying NPS permits and/or buying PS permits
(iv) PS firm selling NPS permits and/ or selling PS permits

(i) An NPS firm buying permits will satisfy 10 and/or 12 as equalities, with 11 and 13 satisfied as inequalities. Accordingly, we will have from 9, 10, and 12

$$(14) \qquad t\frac{\partial \pi_i^r}{\partial \mu_i} = p_r + \frac{\partial TC_b^r}{\partial br_i}$$

$$(15) \qquad \frac{\partial \pi_i^r}{\partial \mu_i} = p_e + \frac{\partial TC_b^e}{\partial be_i}$$

Combining equations (14) and (15), we obtain:

$$(16) \qquad t = \frac{p_r + \frac{\partial TC_b^r}{\partial br_i}}{p_e + \frac{\partial TC_b^e}{\partial be_i}}$$

If there is no transaction cost, $\frac{\partial TC_b^r}{\partial br_i} = 0 \quad and \quad \frac{\partial TC_b^e}{\partial be_i} = 0$. Equations (14), (15) and (16) become

(14’) $t\frac{\partial \pi_i^r}{\partial \mu_i} = p_r$

(15’) $\frac{\partial \pi_i^r}{\partial \mu_i} = p_e$

(16’) $t = \frac{p_r}{p_e}$

Without transactions costs, the marginal willingness to pay for pollution reduction is equal to the permit prices. Since arbitrage leads to indifference between buying and selling alternative permit types, the trading ratio is equal to the price ratio of the two types of permits.

With transactions costs such that $\frac{\partial TC_b^r}{\partial br_i} > 0 \quad and \quad \frac{\partial TC_b^e}{\partial be_i} > 0$, the NPS firm will choose to buy NPS permits so that the private marginal benefit of NPS runoff is equal to the marginal cost of not abating the NPS runoff (which is the sum of price of the NPS permits and the marginal transactions costs required to complete the exchange adjusted by the trading ratio). Similarly, equation (15) implies that the NPS firm will choose to buy PS permits until the marginal private benefit from NPS runoff is equal to the marginal cost of not abating the PS emissions (the sum of PS permit price and the marginal transactions costs involved in buying these permits).

It can, therefore, be seen that the marginal cost of not abating NPS runoff is higher in the case with transactions costs than without transactions costs for a NPS buying permits. The equilibrium number of NPS and/or PS permits purchased by NPS firms in the case of non-linear transactions costs is less than that in the case of costless trade. The magnitude of the reduction in permits traded depends on the marginal impacts of transactions costs.

(ii) An NPS firm selling permits will satisfy 11 and/or 13 as equalities, with 10 and 12 satisfied as inequalities. Accordingly, we will have from 9, 11, and 13

$$(17)\qquad t\frac{\partial \pi_i^r}{\partial \mu_i} = p_r - \frac{\partial TC_s^r}{\partial sr_i}$$

$$(18)\qquad \frac{\partial \pi_i^r}{\partial \mu_i} = p_e - \frac{\partial TC_s^e}{\partial se_i}$$

These results imply that for an NPS permit seller

$$(19)\qquad t = \frac{p_r - \frac{\partial TC_s^r}{\partial sr_i}}{p_e - \frac{\partial TC_s^e}{\partial se_i}}$$

Without transactions costs, $\frac{\partial TC_s^r}{\partial sr_i} = 0$ and $\frac{\partial TC_s^e}{\partial se_i} = 0$, the necessary conditions for a NPS permit seller in equations (17), (18) and (19)become:

$$(17')\qquad t\frac{\partial \pi_i^r}{\partial \mu_i} = p_r$$

$$(18')\qquad \frac{\partial \pi_i^r}{\partial \mu_i} = p_e$$

$$(19')\quad t = \frac{p_r}{p_e}$$

In the absence of transactions costs NPS firms will choose to sell permits until marginal profit from NPS pollution is equal to the permit prices received. With transactions costs, $\frac{\partial TC_s^r}{\partial sr_i} > 0$ and $\frac{\partial TC_s^e}{\partial se_i} > 0$, the marginal profit from NPS pollution for a NPS permit seller is equal to the permit prices minus the transactions costs. Hence, the marginal revenue from selling permits is lower in the presence of transactions costs. NPS permit sellers execute fewer sales of NPS as well as PS permits than in the costless trade case.

Given that NPS sources collectively both buy and sell permits, (16) and (19) imply

$$(20) \quad \frac{p_r + \frac{\partial TC_b^r}{\partial br_i}}{p_e + \frac{\partial TC_b^e}{\partial be_i}} = \frac{p_r - \frac{\partial TC_s^r}{\partial sr_i}}{p_e - \frac{\partial TC_s^e}{\partial se_i}}$$

This condition implies indifference at the margin between being a buyer and a seller of NPS and/or PS permits.

PS Profit Maximization

Similarly, PS firm i (for all i) maximizes its profit

$$\hat{\pi}_i^e = \pi_i^e(e_i) + p_e(se_i - be_i) + p_r(sr_i - br_i) - TC_s^e(se_i) - TC_b^e(be_i) - TC_s^r(sr_i) - TC_b^r(br_i)$$

subject to (4), (5), and (6). The firm's Lagrange function, after combing the constraints, is

$$L_e = \hat{\pi}_i^e + \lambda[t(r_i^0 + br_i - sr_i) + (e_i^0 + be_i - se_i) - e_i]$$

First order necessary conditions include

$$(21)\qquad \frac{\partial L}{\partial e_i} = \frac{\partial \pi_i^e}{\partial e_i} - \lambda_e \le 0\,,\;\; (\frac{\partial L_r}{\partial e_i})e_i = 0\,,\; e_i \ge 0$$

$$(22)\qquad \frac{\partial L}{\partial br_i} = -p_r - \frac{\partial TC_b^r}{\partial br_i} + t\lambda_e \le 0\,,\;\; (\frac{\partial L_r}{\partial br_i})br_i = 0\,,\; br_i \ge 0$$

$$(23)\qquad \frac{\partial L}{\partial sr_i} = p_r - \frac{\partial TC_s^r}{\partial sr_i} - t\lambda_e \le 0\,,\;\; (\frac{\partial L_r}{\partial sr_i})sr_i = 0\,,\; sr_i \ge 0$$

$$(24)\qquad \frac{\partial L}{\partial be_i} = -p_e - \frac{\partial TC_b^e}{\partial be_i} + \lambda_e \le 0\,,\;\; (\frac{\partial L_r}{\partial be_i})be_i = 0\,,\; be_i \ge 0$$

$$(25)\qquad \frac{\partial L}{\partial se_i} = p_e - \frac{\partial TC_s^e}{\partial se_i} - \lambda_e \le 0\,,\;\; (\frac{\partial L_r}{\partial se_i})se_i = 0\,,\; se_i \ge 0$$

As above, we assume (21) is satisfied as an equality, implying that the firm produces. And as above, arbitrage will eliminate opportunities to profit from buying permits simply to sell permits of any given type. Proceeding with the same fashion for the NPS polluters we find that for a PS permit buyer (iii),

$$(26)\qquad t = \frac{p_r + \dfrac{\partial TC_b^r}{\partial br_i}}{p_e + \dfrac{\partial TC_b^e}{\partial be_i}}$$

and it is also the case for PS sellers (iv),

$$(27)\qquad t = \frac{p_r - \dfrac{\partial TC_s^r}{\partial sr_i}}{p_e - \dfrac{\partial TC_s^e}{\partial se_i}}$$

implying that

(28) $$\frac{p_r + \dfrac{\partial TC_b^r}{\partial br_i}}{p_e + \dfrac{\partial TC_b^e}{\partial be_i}} = \frac{p_r - \dfrac{\partial TC_s^r}{\partial sr_i}}{p_e - \dfrac{\partial TC_s^e}{\partial se_i}}$$

The interpretation for the case of PS permit buyer and seller is very similar to that of the NPS firm. Transactions costs induce PS buyers and sellers to execute a lower level of trades in both types of permits compared to that in the case of zero transaction costs. Equation (28) similar to (20) also implies indifference at the margin between being a buyer and a seller of NPS and/or PS permits.

The important point to note is that transactions costs unarguably reduce the volumes of trade for both types of permits. This is consistent with the findings in Stavins' model with uniform point source trading market. The more interesting implication of this trading mechanism, however, is that the presence of four types of transactions costs leads to the segregation of markets into four different classes: NPS buyers and sellers of one or both types of permits and PS buyers and sellers of one or both types of permits.

A graphical example of the optimal market design

In this section a graphical representation rather than a formal theoretical framework on the optimal market design will be provided. Suppose there are only 2 firms, one point source and one nonpoint source in the watershed. The optimal trading equilibrium with and without transactions costs can be depicted in figure 2. The environmental target set by the water quality authority in equation (3) becomes $\mu + e = T + \left(\frac{1}{1-\alpha}\right)^{1/2}\sigma$.

Assuming that the total variance of emissions is positively related to the expected loadings, i.e. as the mean loadings decreases, the total variance of emissions also declines. For the purpose of this example, it is assumed that $\sigma(\mu) = \beta\mu$. The environmental target then can be re-written as:

$$\text{(29)} \quad \left[1-\left(\frac{1}{1-\alpha}\right)^{1/2}\beta\right]\mu + e = T$$

Equation (29) represents the feasible space of different combinations of nonpoint source runoff and point source emissions. The envelope of this function is a straight line with a slope of

$$\text{(30)} \quad \frac{d\mu}{de} = -\frac{1}{1-\left(\frac{1}{1-\alpha}\right)^{1/2}\beta}$$

Since the envelope of the feasible trading space is a straight line, equation (30) can also be considered as the function of the trading ratio. The optimal trading bundle occurs where the profit ratio is tangential to the envelope of the trading space.

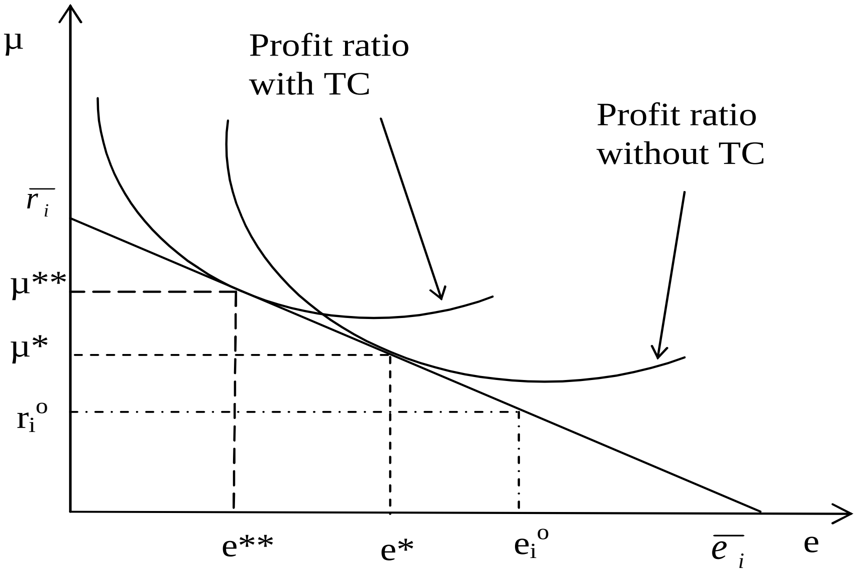

Figure 2. Optimal trading with and without transactions costs

Without transactions costs, the trade volume of point source emissions is $|e_{io}-e^*|$ and that of nonpoint source runoff is $|r_{io}-r^*|$. Under the presence of transactions costs, the optimal level of point source pollution is lower ($e^{**}<e^*$) and the optimal level of nonpoint source runoff is higher ($\mu^{**}>\mu^*$) than those in the case of no transactions costs. With transactions costs, the watershed trading scheme leads to less nonpoint pollution being abated. Given that nonpoint pollution is associated with higher risks, transactions costs actually increase the over all risk level for the agents in the watershed.

Conclusion

Nonpoint source pollution control remains a challenging task for water quality regulators. There have been attempts to design market instruments to mitigate the levels of nonpoint source emissions at least cost. One of those instruments is PS/NPS trading programs. To date, existing programs are of emissions-for-loadings type whereas emissions-for-inputs type market has been theoretically designed. Studies on the performance of these two types of markets have encompassed the uncertainty problem in measuring nonpoint source loadings in their design. They, however, have not dealt with the existence of transactions costs which have potential importance in PS/NPS permit trading. In this article, the impacts of transactions costs on the performance of cap-and-trade point-nonpoint market have been considered. One of the main findings of this article is that there are four different trading classes: NPS firms buying NPS permits and/or PS permits, PS firms buying NPS permits and/or PS permits, NPS firms selling NPS permits and/or PS permits and PS firms selling NPS permits and/or PS permits. Traders are indifferent between individual point sources and indifferent between individual nonpoint sources because transactions costs are the same for individuals within classes. Transactions costs, however, reduce the equilibrium number of permits traded (ps and nps) compared to the costless trade case. By preventing buyers and sellers from trading, transactions costs undermine the efficiency of the trading scheme. Despite the interesting findings, this article is a good starting point for further research. Issues that can be further explored include the implications of spatial variations of firm on the nonpoint loadings and transactions costs, the impacts of market design components (such as the initial allocation, trading ratio and emission target) on the performance of the trading scheme, issues of how to address risks in the design of markets to achieve a first-best allocation.

References

Cason, T. and Gangadharan, L. (2003), "Transactions costs in tradable permit markets: an experimental study of pollution market designs", *Journal of Regulatory Economics*, vol. 23(2), pp. 145-165.

Gangadharan, L. (2000), "Transactions costs in pollution markets: an empirical study", *Land Economics,* vol. 76(4), pp. 601-614.

Horan, R., Shortle, J. and Abler, D., Ribaudo, M. (2001), "The design of comparative economic performance of alternative second-best point/nonpoint trading markets", Staff paper No. 2001-16, Department of Agricultural Economics, Michigan State University, Michigan.

Horan, R., Shortle, J. and Abler, D. (2002), "Point-nonpoint nutrient trading in the Susquehanna River Basin", *Water Resources Research*, vol. 38(5), pp. 1-11.

Horan, R. and Shortle, J. (2005), "When two wrongs make a right: Second-best point-nonpoint trading ratios", *American Journal of Agricultural Economics*, vol. 87(2), pp. 340-352.

Johansson, R. (2002), "Watershed nutrient trading under asymmetric information", *Agricultural and Resource Economics Review,* vol. 31(2), pp.221-232.

Letson, D. (1992), "Point/Nonpoint source pollution reduction trading: an interpretive survey", *Natural Resources Journal*, vol. 32, pp. 219-232.

Malik, A., Letson, D. and Crutchfield, S. (1993), "Point/Nonpoint source trading of pollution abatement: choosing the right ratio", *Agricultural and Resource Economics Review,* vol. 75, pp. 959-967.

McCann, L. and Easter, W. K. (1999), “Transaction Costs of Policies to Reduce Agricultural Phosphorous Pollution in the Minnesota River”, *Land Economics*, vol. 75(3), pp. 402-414.

Montero, J-P. (1997), “Marketable pollution permits with uncertainty and transactions costs”, *Resource and Energy Economics,* vol. 20, pp. 27-50.

Nagurney, A. and Dhanda, K. K. (2000), “Marketable pollution permits in oligopolistic markets with transactions costs”, *Operations Research*, vol. 48(3), pp. 424-435.

Stavins, R. (1995), “Transactions costs and tradable permits”, *Journal of Environmental Economics and Management*, vol. 29, pp. 133-148.

Shortle, J. and Horan, R. and Abler, D. (1998), “Research issues in nonpoint pollution control”, *Environmental and Resource Economics*, vol. 11(3-4), pp. 571-585.

Shortle, J. and Horan, R. (2001), “The economics of nonpoint pollution control”, *Journal of Economic Surveys,* vol. 15(3), pp. 255-289.

Woerdman, E. (2001). "Emissions Trading and Transactions costs: Analyzing the Flaws in the Discussion", *Ecological Economics,* vol. 38(2), pp. 293-304.