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One Step at a Time: Incremental implementation of a water quality permit program

Dennis Collentine, Associate Professor,
Division of Economics, Gävle University,
801 76 Gävle Sweden.
E-mail: dce@hig.se

Abstract

Eutrophication caused by an overabundance of nutrients (nitrogen and phosphorus) in bodies of water is one of the leading water quality issues in developed countries. Achievement of mandated water quality standards has increasingly focused on the role of nonpoint pollution source (NPS) discharges, in particular, runoff of nutrients from agricultural activities. A market for tradable discharge permits (TDP) has the potential of achieving water quality targets in a cost-effective manner. The composite market design is a proposal for an offset type of TDP system that specifically includes agricultural NPS dischargers and addresses both property rights and transaction cost. An integral component of the composite market model is the use of natural science models for calculating nutrient losses.

This paper describes the implementation process for a composite market program in a catchment based on partial information. Implementation is based on a series of steps. In the first step costs are estimated for potential abatement measures in the catchment. In the second step discharge sources are regulated based on the best available technology (BAT) for limiting nutrient losses associated with the targeted activity. This second step creates a potential demand for discharge permits where the constrained sources must choose between investing in the BAT or purchasing permits to allow the estimated level of discharge. Prices for these discharge permits are based on the marginal cost of abatement calculated in the first step. Allowing these permits to be traded increases the economic efficiency of the regulation.

To demonstrate the implementation process, a numerical analysis is performed on a sub-catchment in Sweden. In this study, land use data for selected activities is combined with the modelled effects on nutrient losses from these activities to determine prices for discharge permits, the supply of abatement measures. Hypothetical regulation of selected discharge sources is then used to estimate the demand for permits from these particular sources.

Introduction

"…not all trading programs are equal. Some designs are better than others. Furthermore, one size does not fit all. Emissions trading programs can and should be tailored to each specific application." Tietenberg (2006), *Emissions Trading: Principles and Practices*, p. 207.

The European Water Framework Directive (WFD) has delegated responsibility for management of water resources to the catchment level. Under the guidelines of the WFD the identification of a cost effective program of measures, including the economic and environmental effects of these measures, must be completed and ready to be used by catchment management authorities by the year 2009. One of the major water quality problems which these management plans must deal with is that of eutrophication.

Eutrophication caused by an overabundance of nutrients (nitrogen and phosphorus) in bodies of water is one of the leading water quality issues in developed countries. Achievement of mandated water quality standards has increasingly focused on the role of nonpoint pollution source (NPS) discharges, in particular, runoff of nutrients from agricultural activities (Horan and Shortle, 2005). In the Rönne River basin area of Southern Sweden it is estimated that approximately 75% of the nitrogen loads and 35% of the phosphorus loads reaching the sea are coming from agricultural land use. However, successful programs to reduce losses from nonpoint sources continue to elude authorities and researchers alike.

Numerous abatement measures have been identified which could reduce nutrient losses coming from NPS. Unfortunately, as Shortle et al (2001) noted "the availability of technological solutions only helps to define what is possible, not what is optimal." One of the fundamental questions that must be addressed by catchment managers is how to best allocate scarce resources to achieve the highest degree of abatement. A market for tradable discharge permits (TDP) has the potential of achieving water quality targets in a cost-effective manner.

The use of markets for tradable discharge permits (TDP) as a policy solution has been advocated both by economists and policymakers as the most promising policy alternative since it is a cost-effective means of meeting water quality targets. The United States Environmental Protection Agency in a recent report (EPA, 2003) "believes that market-based approaches such as water quality trading provide greater flexibility and have potential to achieve water quality and benefits greater than would otherwise be achieved under more traditional regulatory approaches" and that "market-based programs can achieve water quality goals at a substantial economic savings". A trading program through "introducing transferability … offers the potential for substantially lowering costs and for encouraging technological [abatement] progress" (Tietenberg, 2000, p.176). Unfortunately, the attempts to start up permit markets that are able to exploit abatement cost differences between sources have not met with the success expected (EPA, 2001).

The composite market design is a proposal for a TDP system that specifically includes agricultural NPS dischargers and addresses both property rights and transaction cost problems (Collentine, 2006). An integral component of the composite market model is the use of natural science models for calculating nutrient losses. The simulated quantification of losses allows these modelled values to be used for assigning limited property rights to NPS discharges. The structure of the composite market allows this system to be phased in over time with existing institutions and limited demands on financing.

This paper describes the implementation process for a composite market program in a catchment based on partial information. Implementation is based on a series of steps. In the first step costs are estimated for potential abatement measures in the catchment. In the second step discharge sources are regulated based on the best available technology (BAT) for limiting nutrient losses associated with the targeted activity. This second step creates a potential demand for discharge permits where the constrained sources must choose between investing in the BAT or purchasing permits to allow the estimated level of discharge. Prices for these discharge permits are based on the marginal cost of abatement calculated in the first step. Allowing these permits to be traded increases the economic efficiency of the regulation.

To demonstrate the implementation process, a numerical analysis is performed on a sub-catchment in Sweden. In this study, land use data for selected activities is combined with the modelled effects on nutrient losses from these activities to determine prices for discharge permits, the supply of abatement measures. Hypothetical regulation of selected discharge sources is then used to estimate the demand for permits from these particular sources.

Water quality trading

Trading is a relatively recent innovation in environmental management. Original contributions by Crocker (1966) and Dales (1968) established a theoretical basis for trading. However, it was only when policymakers in the US felt that the continued use of more stringent legal regulation would be a serious impediment to economic growth that trading was turned to as a policy alternative (Tietenberg, 2006). Trading offered a way for regulators to establish air quality targets under the Clean Air Act that allowed polluting activities the flexibility of meeting standards through directly investing in abatement practices or indirectly investing in abatement through the purchase of a use permit. Both of these alternatives, direct and indirect investment, would bring the cost of pollution into production costs. From an economic perspective bringing the cost of pollution into a market would allow prices to serve as a method for allocating scarce resources and promote economic efficiency. The interest in the use of trading as an instrument for achieving water quality goals is a direct result of earlier success with trading for achieving air quality goals. Therefore, in order to understand how trading program design concepts have evolved it can be instructive to follow the development of air quality trading programs.

The first trading programs evolved in regions that were designated under the Clean Air Act as substandard and where enforcement of standards under the act was expected to have a dampening effect on economic growth (Tietenberg, 2006). These programs were called "offset" programs. Before new industry (economic growth) would be allowed in impacted areas they needed to offset their expected effect on air quality by financing emission reductions from existing sources. Existing sources could reduce emissions by investing in abatement technology or by lowering production and thereby emissions. This established a market in permits with existing sources providing a supply of emission credits and new sources a demand for credits and the combination of these a price for the transfer of emission "rights". This type of market for emissions also was cost efficient because there was an economic incentive for new sources to find the lowest cost alternative for purchasing abatement, the greatest amount of emission abatement for every dollar spent. Environmentally, as long as ambient standards in the impacted region were met the source was of emissions was not important. A new promising instrument for environmental policy was launched.

From the start, emission trading programs were recognized to have limitations. For the offset trade to have a positive impact on pollution, source emissions needed to be substitutable both spatially and temporally. This led to the idea that if a "bubble" could be defined geographically as an area in which emissions were substitutable that trading between sources in this area would then be compatible with environmental targets. The idea of credit "banking" was a resolution of the temporal substitutability problem. The scope of trading programs expanded rapidly to include not only ambient air quality standards but also specific air pollutants (lead, ozone-depleting gases, sulfur dioxide) and water pollutants.[1] The bubble concept was based on the definition of some type of threshold for allowable pollutants within the bubble. The threshold defined the acceptable level of the particular pollutant (or ambient standard) in the bubble. Since emission sources within the bubble were considered to be

[1] See Tietenberg (2006) Chapter 1 for a short history of the evolution of pollutant trading and overview of trading porgams.

substitutes then demand for credits could also be driven through the use of a threshold which constrained existing sources in the bubble, a "cap" on emissions. This opened up new possibilities for using trading systems. The use of the cap concept opened the way for regulatory authorities to establish environmental targets which could create demand for emission permits from not only 'new' emission sources in the bubble but also existing sources.

Cap and trade became the generally accepted way for defining trading programs (Tietenberg, 2007; Tientenberg, 2006; Ellerman 2007). Under this system the cap could be used for determining initial allowances. Existing sources could be given an allowance as a share of the cap based on some type of historical use. Distribution of these initial allowances was a political issue. From an economic perspective the prevailing consensus was that while the choice of allocation method would affect economic rents for existing sources, in the long run any method of distribution would result in economic efficient abatement.[2] Political consensus for the use of trading as an economic instrument for the attainment of environmental goals was not hard to achieve. Existing sources could receive initial allowances that provided an asset which would increase in value as thresholds (caps) were lowered over time, regulatory agencies could meet environmental targets and politicians could point out how trading programs realized the polluter pays principle by explicitly recognizing the social cost of pollution control. Following the development of cap and trade principles for air quality management these same principles were then applied to water management. However, they did not meet with the same degree of success.

The United States Environmental Protection Agency (EPA, 2003) "believes that market-based approaches such as water quality trading provide greater flexibility and have potential to achieve water quality and benefits greater than would otherwise be achieved under more traditional regulatory approaches" and that "market-based programs can achieve water quality goals at a substantial economic savings". While it is recognized that trading programs have this potential, two years earlier the same agency reported in a comprehensive study (EPA, 2001) that "effluent trading has yet to live up to its full promise" (p.99), a situation which unfortunately has not changed in the interim (King and Kuch, 2003; Breetz et al, 2004; King, 2005; Collentine, 2005a).

Figure 1: Regulation of agricultural activities and the supply and demand for permits

- Alternative 1a: If all producers of cereal crops sown in the spring in Nitrate Vulnerable Zones (NVZ) are expected to sow a catch crop, then a producer who wished to not sow a catch crop would need to compensate for the infringement by paying the social (opportunity) cost for the expected excess discharge. In the composite market trading program this is calculated as the marginal cost of a comparable reduction from another source, the price of a permit.
- Alternative 1b: If sowing catch crops were an elective measure (not required) then society would need to compensate the producer for the infringement by paying the opportunity cost to induce them to choose to sow a catch crop. In a composite market program this producer could generate a discharge credit which could be sold.
- Alternative 2a: If an acceptable fertilization practice ("good agricultural practice") for spring-sown grains was determined to be 100 kg N/ha for land within NVZs then in a composite market scheme a producer who wished to exceed this rate must offset this through a purchase of permits for the estimated excess N losses associated with the higher rate.
- Alternative 2b: Under the same baseline condition a producer who used less then 100 kg N/ha would have an opportunity to sell the reduced N loss associated with the lower rate. However, this does not mean that a buyer would be found (a credit created).

[2] However, Horan and Shortle (2005) suggest that there may be distortions in efficiency from initial allocations due to trading rations.

Two of the problems that have limited the development of TDP markets that include NPS dischargers are that property rights must be assigned before it is possible to transfer the right of ownership inferred by a permit system and market participants incur costs in their search for information necessary to evaluate transactions (Collentine, 2006). A third problem is that of the more than 70 trading initiatives for water quality in 2004 in the US, all of these have been based on the cap and trade concept (Breetz et al, 2004). This is in part due to the above described evolution of the trading program concept as well as the fact that the environmental regulation that is available for driving demand for permits is based on EPA total maximum daily load (TMDL) guidelines. There is a basic understanding that TMDLs will serve as a sufficient constraint on loads to lead to source trading (EPA, 2007).[3] However, since TMDLs do not specifically address discharges from NPS then initial allocation for specific nutrients in specific watersheds is not possible and demand is expected to be driven solely by constraining point sources. For point sources the choice between investing in BAT with a high degree of certainty with respect to costs and effects or purchasing permits from NPS with a high degree of uncertainty is relatively easy, they invest in abatement technology.

These three problems (transaction costs, property rights and determining a cap) combine to limit or restrict possible trades. The model described below, the composite market model, addresses all three of these problems. The first of these two through the disaggregating of trading into separate markets and the third through constraining NPS incrementally in what may be regarded as an extension of the original type of offset model for a trading program. In the proposed composite market rights are determined by a baseline of acceptable practices for each polluting related activity. When an activity has been regulated (see Figure 1 for two examples) loads above the acceptable limit become 'new' sources in a catchment that must be either reduced to comply with regulation or offset through the purchase of permits which represent a reduction at another source. In this way incremental implementation of the type described below in an composite market program will lead to the achievement of environmental targets 'one step at a time'.

The Composite Market System

The composite market disaggregates permit transactions into two primary markets and one secondary market (Figure 1). Following the typology of water quality trading programs defined by Woodward et al (2002), the composite market combines qualities of both the exchange and clearinghouse structures. In a clearinghouse structure, an institution performs a role as a broker between sellers of discharge control and buyers of the credits created. A clearinghouse precludes the need for bilateral contacts between buyer and seller by providing price information to each of these actors as well as providing a market for the individual transactions. The two primary markets serve as a clearinghouse for sellers of performance contracts and buyers of discharge permits. This greatly reduces the information transaction costs for the individual sources (Woodward et al, 2002). In addition, where marginal transaction costs are decreasing with respect to the number of transactions performed this will also result in falling costs for participation in a TDP system.

The secondary market, like an exchange, is "characterized by its open information structure and fluid transactions between buyers and seller" (Woodward et al, 2002). The public availability of information about market clearing prices ensures that information transaction costs are minimal. The liquidity in this market also makes it easy for actors to enter into and get out of transactions, which reduces the uncertainty of taking a position in the market. The combination of these effects produces an institution "very close to achieving the fully efficient allocation where any trade that would make both the buyer and seller better off is fulfilled" (Woodward et al, 2002).

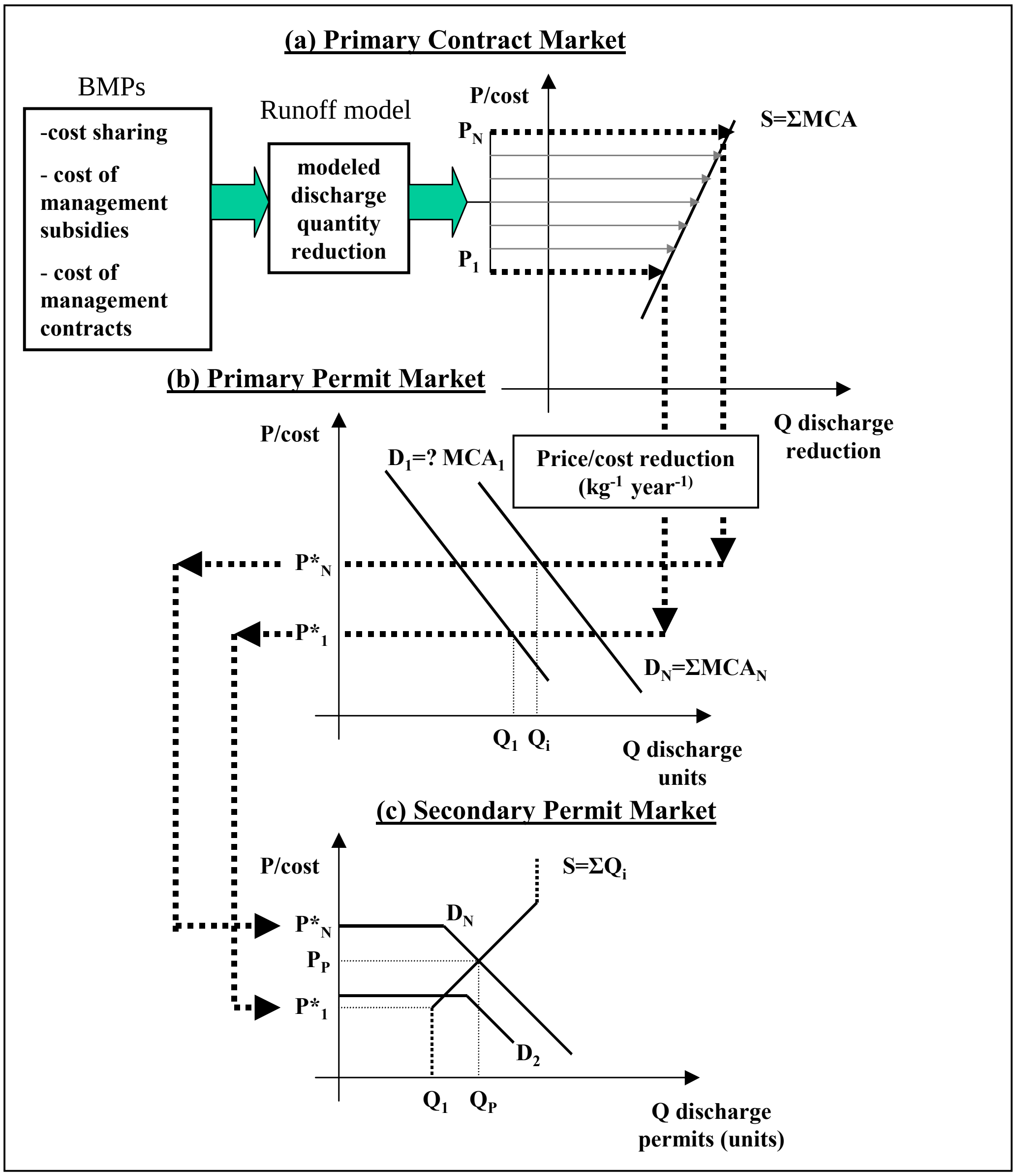
[3] "The *Water Quality Trading Toolkit for Permit Writers* is EPA's first "how-to" manual on designing and implementing water quality trading programs. The Toolkit helps National Pollutant Discharge Elimination System (NPDES) permitting authorities incorporate trading provisions into permits. It will help improve the quality and consistency of all trading programs across the nation." (EPA,2007)

A TDP system based on three markets allows permit trading to be separated into individual functional components. Coordination in the composite market system consists primarily of the flow of price information between the three markets illustrated in Figure 1.

Primary contract market: The supply curve for abatement measures

There are two types of actors active in a primary contract market. On the one hand, the supply side, there are dischargers, who through adoption of control (abatement) technology have the possibility of reducing their discharges. On the other hand, the demand side, there is a local catchment authority with a budget for purchase of discharge reducing measures. Purchases of measures by governmental agencies already take place in many catchment areas in the form of programs to induce agricultural dischargers through economic incentives (cost sharing or direct subsidies) to adopt abatement measures.

Figure 2. The composite market model for transferable discharge permits.



Support for adoption of measures may be either based on a uniform price for the measure, a subsidy or some other type of fixed or predetermined payment, or be in the form of an individualized performance contract, for example using reverse auctions. Under an individualized contract the level of payments is assumed to be variable but related in some way to a discharge reduction activity. Examples of existing programs which support the adoption of BMPs on farms include direct payment for taking cultivated land out of production (wetlands or buffer strips), payments to compensate for reduced expected yields (catch crops, reduced fertilization, tillage techniques or timing), cost sharing (manure storage or adaptation of drainage systems), and the provision of information through existing channels (extension services or agricultural producer organizations). These types of programs may be national but implementation is often delegated to regional institutions and accompanied by a budget for supporting them.

The necessary step for the transformation of BMP programs of this type, into credits in a TDP program lies in the quantification of the expected effect of the BMP on discharges by the adopting source (see Figure 1a). Modeling offers a possibility for site-specific quantification of the effect of BMPs when adopted by individual producers. In essence, the use of modeling transforms the NPS discharge into a quasi-NPS discharge or what perhaps may be best described as a model generated PS.

The sum of all these model transformed marginal abatement costs generates the supply curve in the primary contract market in Figure 1a. Each time the catchment agency enters into a contract with a pollution source more information becomes available with respect to marginal abatement costs. In an idealized market of this type a purchasing agency with full abatement cost information would always purchase the least cost measures first. In the model this gives rise to the upward sloping MCA/supply curve depicted in Figure 1a. In practice, incomplete information or particular forms of transactions, such as uniform BMP support programs, may lead to model generated MCAs that vary in order (not always chronologically ascending from least cost to higher cost measures). However, this does not present a problem since the agency unilaterally determines which price to use as the ‘last’ price from this market to be transferred to the primary permit market. The price of permits in the primary permit market represents the marginal abatement cost determined in the primary contract market, the main function of this market. The modelled discharge reduction quantities in the primary contract market used to calculate marginal abatement costs are presumed to represent the reduction target for catchment water quality. The ultimate goal of any TDP system is to achieve a targeted level of discharges. This is true for thecomposite market system as well, the major difference is that reductions are phased into the system through activities in the two primary markets.

Primary permit market: The demand curve for emission permits

The purpose of this market is also twofold; to issue discharge permits, and to provide a price anchor for dischargers to use in making abatement investment decisions. The two types of actors in this market are a regulatory authority, for example a catchment agency, on the supply side of the market and potential dischargers on the demand side. The good traded in the market is a limited set of property rights, quantified as a discharge volume based on the modeled effect on the recipient that is transferable pursuant to approval by the issuer. In the program design discussed in this paper, this good is an annualized volume in kilograms, of nitrogen or phosphorus discharge measured at a particular recipient in a catchment area for a specified number of years. Prices are therefore defined either explicitly or implicitly as a price per kilogram of discharge to the recipient.

The primary permit market is a unique allocation method for discharge permits in a TDP system. The buyers market phases in the quantity of discharge permits issued over time. This contrasts with other TDP systems that require the quantification of total discharges in the trading area as the first step in initiating a trading program (Hahn and Hester, 1989; Horan et al, 2002). In a conventional program it is assumed that determination of total discharges is necessary both for allocating discharge rights and simultaneously constraining discharges to create a market. In the composite market approach, rights are assigned through the sale of permits as different sectors of dischargers are constrained into making a choice between purchasing permits for planned discharges in excess of the allowed level or investing in abatement. Allocation takes place each time a discharger purchases (is issued) a permit in this market. Permits that are issued represent limited property rights in the form of a fiat value for a discharge quantity allowed under the terms of the permit. The number of permits required is calculated based on the modelled effect at the recipient as described in the section above under the primary contract market, i.e. the normalized unit value of the permit. A willingness to sell a permit is an indication on the part of the regulatory agency, the seller, that the allocation is positive with respect to the environmental benefits for the catchment under its jurisdiction. The agency only needs to have a way of evaluating the incremental effect of the permit sale on the targeted recipient.

The primary contract market is a source of this information. As noted above, this is done by assigning a value to discharge transfers in this market using the price paid, either directly as an individualized contract or indirectly as a subsidy, and the modeled effect of the reduction which then is the price transmitted to the permit market (see Figure 2). Therefore, when the agency chooses to sell a discharge permit, the sale price represents the marginal cost of abatement for discharges to the targeted recipient in the catchment area. The volume of discharges allowed under the permit corresponds to abatement measures evaluated at the margin, that is, the value of reductions either recently purchased or reductions that may be purchased. The price in the permit market is not fixed but flexible and reflects the supply of abatement measures and the demand for discharge permits.
Policies targeting pollution reduction based on economic incentives need to include an element of source control to create markets. For a market in TDPs to exist, dischargers must be choice constrained. There needs to be methods to regulate discharge levels or activities which will lead to a demand for source compliance either through purchase of permits or investment in abatement measures. Within the composite market system, sources are expected to be constrained incrementally over time. In the very long run the sum of these partial constraints may be equivalent to a discharge cap. In the short run the goal for the catchment agency is to identify sectors that may be controlled in a cost efficient manner.

Supply and demand for permits in the Rönne River Basin

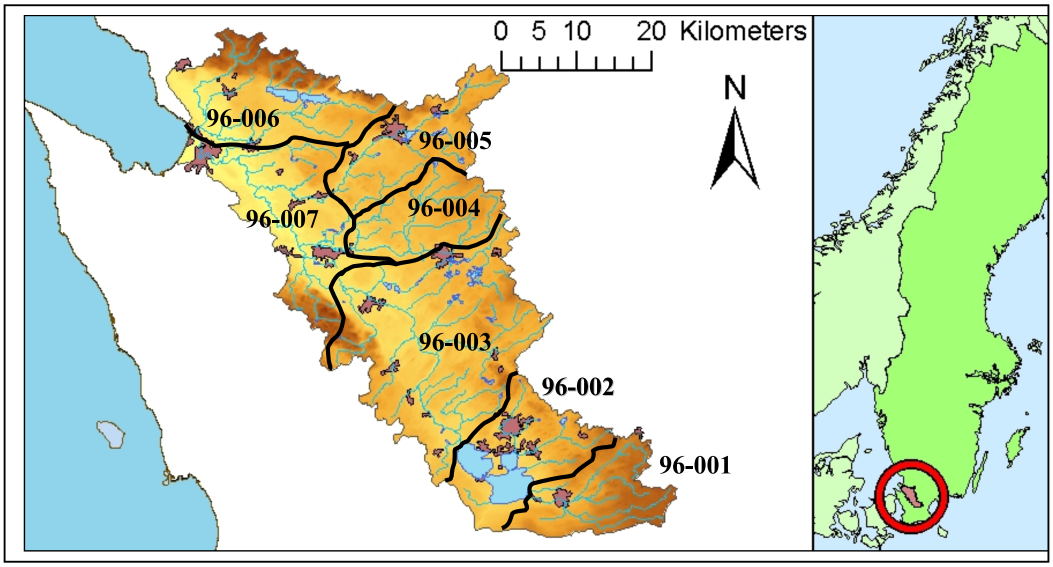
The Rönne River basin described below serves to first demonstrate how program supported abatement measures may be combined with leaching models to estimate abatement costs from catchment data to develop a supply curve for abatement credits that may be used for permit price setting. This is followed by a description of how enforcement of existing regulation for individual household septic systems can lead to demand for permits. Finally this example shows how the supply and demand can be combined in a composite market trading permit program.

The Rönne River basin

The Rönne River drains a large area of Southern Sweden (1900 km^2) and empties into the Kattegatt area of the Baltic Sea on the Swedish west coast (Figure 2). The river basin has a total population of 100,000 with about 70% living in urban areas. Around 31% of the basin land area is fertile highly productive agricultural land with approximately 55,000 ha under cultivation (Table 1). The remainder is primarily in privately managed forest area (48% of the area). At the headwaters of the river there are three large lakes with a surface area of approximately 40 km^2 that are important as a recreational area. The Rönne basin has a history of high levels of nutrients transported by surface water to the Kattegatt where eutrophication is a problem.

In a comprehensive national study over nitrogen loads from Swedish land areas to surrounding seas, the TRK (Transport – Retention – Source) project, the basin area was divided into the set of seven sub-catchments depicted in Figure 2 (from TRK at www-nrciws.slu.se/TRK/index.html). Retention data from this study was used to calculate total loads measured as N losses at the root zone using the SOILNDB model minus background losses (before retention) and the share of this load from land use in the basin registered for EU agricultural program support. The annual transport of nitrogen from the basin to the sea is approximately 2,200 tons of which the contribution from cultivated land is around 1,300 tons (TRK).

Figure 2. The Rönne River basin, sub-catchments (TRK)



Cultivated soils in the basin consist primarily of three types; loam, sandy loam and loamy sand. The distribution of these soils is estimated in Table 1 as a percentage of agricultural soils for each of the seven sub-catchments (Lidberg et al, 2003). Since the two BMPs used in this study (described below) are recommended for use in cultivation of spring cereals (spring barley, spring wheat and oats) the area of each soil type in Table 1 is calculated as the percentage of total cultivated land sown in these three cereals in the catchment in 2003, that is, 53% of the area of each soil type (SCB, 2004).

Catch crop and spring tillage subsidy programs

Cultivation practices that can reduce nitrogen leaching have been supported in Sweden through a program of subsidies directed at specific regions, including the Rönne River basin. Two of the agri-environmental programs aimed at reducing nutrient losses from farming practices through payments to land owners are a catch crop program and a spring tillage program. The original goal of the catch crop program when it was initiated in 1995 was that 39,000 hectares in Southern Sweden, the designated support area, would eventually be signed up with the program.

The level of compensation was set at 62.50 USD^{-ha} [4]. During 1996, a little over 4,800 acres, representing around 12% of the goal, were included in the program. Due to this low interest the compensation level was almost doubled in 1998 to 112.50 USD^{-ha} after a recommendation by the Swedish Board of Agriculture. This increase led to a somewhat higher participation rate, an enrolment of 7,900 hectares or about 20% of the target level but the low level of participation led to a new set of recommendations from the Board of Agriculture. Participation rules were relaxed with respect to dates for sowing and plowing in the catch crop and complementary payments could be received for delayed cultivation, spring tillage. (SOU, 1999). Current new rules have led to oversubscription in the program the question of which factors led first to the lower than expected participation rate and then to the greater than expected participation rate have yet to be understood (Collentine, 2002). The two programs may be entered into for a five year period either together with annual compensation at 162.50 USD^{-ha}, or seperately at 112.50 USD^{-ha} and 50 USD^{-ha} respectively.

[4] The exchange rate used in this study is 8 SEK^{-USD}.

Table 1. Rönne River catchment area by sub-catchment; land area, cultivated land, three soil types as a percentage of the total area in the sub-catchment, total estimated number of hectares per soil type in each sub-catchment with a potential for catch crops and/or spring tillage, gross loading of N in tons, and net loading as a percentage of the total load. (Source: Data adapted from TRK and Lidberg et al, 2003).

	subcat 96-001	subcat 96-002	subcat 96-003	subcat 96-004	subcat 96-005	subcat 96-006	subcat 96-007	Total
Total land area	15300	24200	55800	24100	19100	26100	24900	190000
Cultivate land	7100	7100	14400	3700	2000	7700	12500	54600
loam	0%	9%	30%	15%	13%	17%	31%	21%
ha	0	342	2290	302	133	680	2056	6068
loamy sand	0%	9%	7%	8%	25%	8%	10%	9%
ha	0	342	509	151	265	340	685	2567
sandy loam	100%	82%	57%	77%	50%	42%	34%	56%
ha	3763	3079	4325	1508	530	1700	2284	16103
Gross N load	212.4	198.7	296.2	67.0	41.4	358.5	539.9	1714.1
Net N load (%)	47%	41%	83%	81%	82%	72%	84%	72%

Modelled leaching estimates

Root zone leaching estimates were made within the TRK program using data from the SOILNDB model (Johnsson and Mårtensson, 2002). The leaching estimates in Table 2 are for spring barley on the three different types of soil for four sets of cultivation practices; no measures, combined catch crop and spring tillage, catch crop only and spring tillage only. The leaching estimates for the two other cereals are similar but separate estimates for each soil type in the catchment were not available.

Table 2: Rönne River catchment area; estimated leaching by soil type and applied best management practice (kg^{-ha}) and subsidy for each measure (USD^{-ha}). (Source: Adapted from Lidberg et al, 2003).

	loam	Loamy sand	sandy loam	subsidy USD^{-ha}
No measures applied	53	70	62	
Catch crop and spring tillage (reduction)	29 (24)	36 (34)	33 (29)	162.50
Catch crop only (reduction)	38 (15)	51 (19)	44 (18)	112.50
Spring tillage only (reduction)	45 (8)	58 (12)	52 (10)	50

*Table 3a: Cost per kg for subsidized agricultural abatement measures in the Rönne River catchment area; sub-catchment estimated cost per unit of **net** leaching reduction by soil type and applied best management practice (USD^{-kg}).*

	subcat 96-001	subcat 96-002	subcat 96-003	subcat 96-004	subcat 96-005	subcat 96-006	subcat 96-007
Catch crop and spring tillage							
loam	14.40	16.51	8.16	8.36	8.26	9.40	8.06
loamy sand	10.18	11.66	5.76	5.90	5.83	6.64	5.69
sandy loam	11.93	13.66	6.75	6.91	6.84	7.79	6.68
Catch crop only							
loam	15.96	18.29	9.04	9.26	9.15	10.41	8.93
loamy sand	12.60	14.44	7.14	7.31	7.23	8.23	7.05
sandy loam	13.30	15.25	7.53	7.71	7.63	8.68	7.44
Spring tillage only							
loam	13.30	15.25	7.53	7.71	7.63	8.68	7.44
loamy sand	8.86	10.16	5.03	5.15	5.09	5.79	4.96
sandy loam	10.64	12.20	6.03	6.18	6.10	6.95	5.95

*Table 3b: Total potential reduction for subsidized agricultural abatement measures in the Rönne River catchment area; **net** estimated leaching by soil type and applied BMP (in tons).*

	subcat 96-001	subcat 96-002	subcat 96-003	subcat 96-004	subcat 96-005	subcat 96-006	subcat 96-007
Catch crop and spring tillage							
loam	0	3.4	45.6	5.9	2.6	11.7	41.4
loamy sand	0	4.8	14.4	4.2	7.4	8.3	19.6
sandy loam	51.3	36.6	104.1	35.4	12.6	35.5	55.6
Catch crop only							
loam	0	2.1	28.5	3.7	1.6	7.3	25.9
loamy sand	0	2.7	80.2	2.3	4.1	4.7	10.9
sandy loam	31.8	22.7	64.6	22.0	7.8	22.0	34.5
Spring tillage only							
loam	0	1.1	15.2	2.0	0.9	3.9	13.8
loamy sand	0	1.7	5.1	1.5	2.6	2.9	6.9
sandy loam	17.7	12.6	35.9	12.2	4.3	12.2	19.2

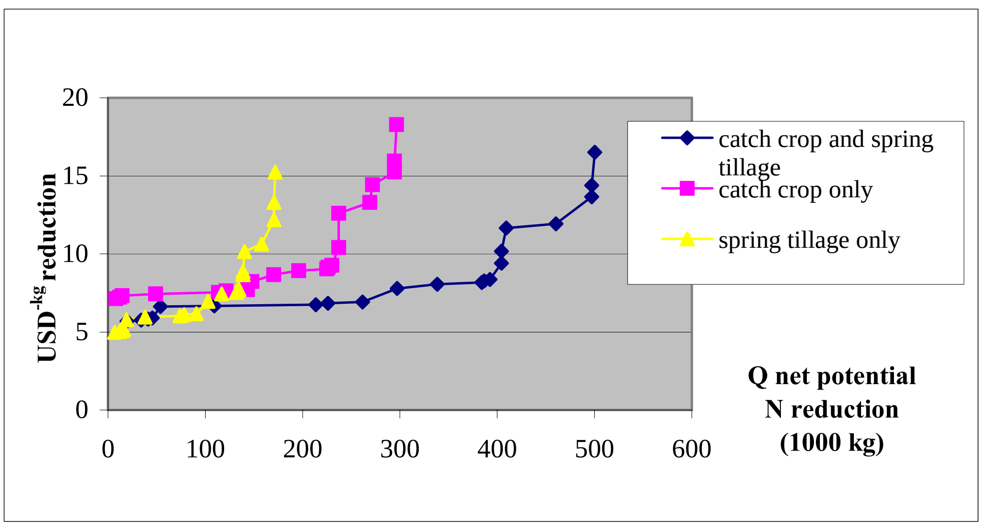
Subsidies for the three sets of BMPs were combined with estimated leaching by soil type to calculate the cost per kilogram of the reduction in root zone leaching by measure and soil type.
These estimates were combined with retention estimates for each sub-catchment to produce the estimated cost per net unit of reduction (load to the sea) and potential reduction for each of these sub-catchments (Tables 3a, 3b). The potential reduction for each soil type in the catchment was calculated from the total cultivated area in the catchment with a potential for applying the measures (Table 1). This last set of tables (Tables 3a, 3b) contains all the information needed to construct supply curves for marginal abatement in the catchment.

Estimating the supply curve for abatement measures

The first step in implementing the composite market permit scheme is the determination of a price for issuing discharge permits. The function of the primary contract market in the model (see Figure 1a) is to gather information for pricing permits through the development of a supply curve for abatement measures. This supply curve describes marginal abatement costs for reducing pollutants in a particular area (river basin, watershed). Derivation of the abatement supply curve requires estimates of the cost per unit of reduction as well as the expected quantity of potential reduction for that unit cost. This in turn requires data on the cost of abatement measures and the expected effect on discharge volumes from these measures.

The supply curves in Figure 3 represent graphically the data from Tables 3a, 3b. The cost on the *y* axis in the diagram is the calculated cost per unit of reduction from the three measures. This is the cost that is hypothetically paid by the purchasing agency, in this case the Swedish Board of Agriculture, for the BMPs which generate the reduction. It may be regarded as the price which society pays to purchase the corresponding reductions. The quantities on the *x* axis are the potential reductions associated with each price. In theory this is the volume of reduction which could be obtained at that particular cost per unit. Since the costs are calculated upon the premise that the subsidy for each measure is acceptable to all farmers in the area, the cost is a low estimate of the actual costs. The measures in the supply curves are not aggregated because they represent a discrete choice for cultivation practices on a particular field. Choosing one of the measures precludes the possibility of choosing one of the remaining two measures.

Figure 3. Supply curve for selected BMPs in the Rönne River basin by soil type and sub-catchment area retention.



Regulation of household septic systems

Current Swedish regulations require that household septic systems are able to remove 50% of the nitrogen and 80 % of the phosphorus entering the system. These function related standards were based on available technology for these systems. There are several techniques which can be used to meet these standards. Installations with infiltration beds and sludge separation are the most effective and are estimated to remove 79% of the nitrogen and 89% of the phosphorus entering this type of system. While a system with only an infiltration bed is slightly less effective, reducing estimated nutrient discharges by 76% for N and 88% for P, it is still acceptable for conforming to standards.

When these standards were put into effect by the Swedish Environmental Protection Agency in 2006 it was estimated that nationally 40% of the existing 1 million household systems were substandard and would need to be upgraded to comply with the new regulation (Palm et al, 2006a). Compliance with the new functional standards would impose a significant cost on individual households in rural areas and although many of these substandard systems were for second homes there are an increasing number of these that serve as permanent residences.[5]

Modeled loading estimates

Loading estimates for household systems within the Rönne River Basin can be seen in Table 4. The number and type of systems were based on a survey of county authorities in Sweden in a report performed for the Swedish EPA (Ryegård et al, 2006) The loading estimates are from the same report and include adjustment for household size and type of residence (year round or second home). The six counties in Table 4 are not contiguous with the Rönne catchment area but include those counties that are primarily defined by the catchment boundaries. The counties are divided into two groups (A,B) that correspond to their location in the catchment with respect to the Baltic Sea as a recipient. In the map in Figure 2 the two Group B counties (Hörby and Höör) are primarily in the sub-catchment areas 96-001 and 96-002, the two sub-catchments located furthest away from the recipient.[6] The gross loads are calculated as the loss within the sub-cactchment . The net loads for the two groups in Table 6 are calculated using the TRK retention coefficients in Table 1 above. The numbers in the first column correspond to the estimated gross loads from the two types of substandard systems in Table 4.

Table 4. Estimated gross N loads from septic systems in the Rönneå catchment that do not comply with standards

County and group (A,B)	Number of septic systems [1]	Type of system Sludge separation Number (gross load) [2]	Type of system Stenkista, rensbrun Number (gross load) [3]
Ängelholm (A)	2914	670 (4080 kg/yr)	612 (4284 kg/yr)
Örkelljunga (A)	1992	124 (755 kg/yr)	42 (294 kg/yr)
Klippan (A)	1732	183 (1114 kg/yr)	74 (518 kg/yr)
Perstorp (A)	722	722 (1145 kg/yr)	31 (217 kg/yr)
Group A gross load		7094 kg/yr	5313 kg/yr
Hörby (B)	3170	792 (4823 kg/yr)	136 (952 kg/yr)
Höör (B)	2503	651 (3965 kg/yr)	108 (756 kg/yr)
Group B gross load		8788 kg/yr	1708 kg/yr
Total gross load		15881 kg/yr	7021 kg/yr

[1] PLC5 (Ryegård et al, 2006)
[2] Estimated loading 7 kg/yr and removal rate (13%), (Ryegård et al, 2006)
[3] Estimated loading 7 kg/yr and removal rate (0%), (Ryegård et al, 2006)

[5] In a survey in 2000 it was estimated that around 70% of household septic systems were for second homes. However, between 1990 and 2005 17 % of the stock of second homes was converted to year round residences. The estimated cost for upgrading systems to the functional standards are between 100000-120000 SEK (12500-15000 USD) per system. (Palm et al, 2006).

[6] The retention coefficients are similar within these two groups (Table 1) and since the geographical borders of the sub-catchments areas in Figure 2 do not correspond well with the county borders used for estimating the numbers of and types of septic systems this measure were used.

Table 5. Estimated <u>net</u> N loads from septic systems in the Rönneå catchment that do not comply with current standards

Group	Gross load N kg/year	Transport Coefficient	Net load N kg/year
Group A	7094 + 5313	80%	9925
Group B	8788 + 1708	45%	4723
Total			14648*

*Arheimer et al (2006) estimated this at 17.78 t/yr

Estimating the demand for permits

As can be seen in Table 4 the estimated net load of nitrogen to the sea from substandard household septic systems in the Rönne catchment is estimated at around 14.6 tonnes. What would it cost to reduce the N load to the sea by 14, 6 tonnes from another source such as agriculture? The answer can be found in Tables 3a and 3b (and in the supply curve for abatement measures). The kilogram cost for reducing 14.6 tonnes of N to the sea is 5.09 USD/kg, in terms of the subsidy and the effect on reduction of spring tillage on sandy loam in sub-catchments 96-003, 96-005 and 96-007. That is, paying farmers in those three sub-catchments to plow their fields in spring (rather than earlier) would cost 50 USD/ha and reduce the N load to the sea by 14,6 tonnes.

The number of permits which every property owner that does not want to upgrade their septic system to comply with standards must have depends on the type of septic system and sub-catchment location. Table 6 provides this information for the two types of sub-standard systems in the two areas in the catchment. If a property near the coast (in Group A) presently had only sludge separation for wastewater treatment then they would need to hold permits that correspond to a 4.87 kg annual reduction if they chose not to upgrade their system. At a cost of 5.09 USD/kg this amounts to an annual cost for the property owner of 13.50 USD/year. The owner can compare this with the estimated annual cost for required improvements, assuming a 30 year life for the system an average investment cost of 14,000 USD and a simple rate of interest of 5% this amounts to around 1150 USD/year.

Table 6. Estimated N load to the sea by type of septic systems and sub-catchment location, annual cost valued at 5 USD/kg

Type of system	Subcatchment A Load kg/year	Cost	Subcatchment B Load kg/year	Cost
Stenkista	5,6	28 USD/yr	3,15	15.75 USD/yr
Sludge seperation	4,87	24.50 USD/yr	2,74	13.50 USD/yr

This is not a measure of the cost savings of a tradable permit system but only an indication that there would be an interest in trading. Permit quantities need to be normalized (one kg N to the sea), administration costs included and permits need to be time specified. The large price difference may also be an indication that sources which are regulated early in a composite market program may receive significant economic rents. This is due to the fact that offset permits are calculated as the marginal abatement cost of the estimated load from that source and as expected and can be seen in Figure 3 marginal abatement costs are upward sloping. It should be noted that the number of permits refers only to N loads, in the case of septic systems there would also need to be a permit for P loads as well.

Conclusions

The purpose of this study has been to study how supply and demand for permits can be generated for a particular catchment area in a composite market trading scheme. There is a positive relationship between the level of abatement and the cost per unit of reduction, as the level of reduction increases the cost per unit increases. A watershed agency can use this information to set a price for the sale of permits to other sources which may be interested in the purchase of permits as an alternative to investing in required abatement measures This is the principle of economic efficiencies that make a tradable permit system interesting, increasing the total level of abatement at the lowest cost.

The study illustrates clearly how economic variables can be combined with bio-physical process models to quantify the effect of agronomic practices on nutrient losses. This in turn makes possible the creation of limited property rights which are a prerequisite for a successful trading scheme. The study also illustrates how environmental regulation creates demand for discharge permits and how agri-environmental programs can provide information for pricing and allocating permits.

Further research

This study illustrates the methodology for generating abatement supply curves and estimating permit prices based on demand. While the method may be generalized to set prices in other trading schemes, the partial nature of the supply curve where data is phased in as it becomes available is particularly appropriate where the permit issuing market is also phased in over time. Additional measures should be included in future studies to increase the amount of information, and sources, in the abatement supply curve. In addition, other regulatory schemes for constraining discharge sources must be studied to estimate the potential for creating a market in permits.

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