Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Department of Economics

WORKING PAPER
02/2013

Market power and double-dipping in nutrient trading markets

Gren, Ing-Marie
Elofsson, Katarina

Economics

Sveriges lantbruksuniversitet, Institutionen för ekonomi
Swedish University of Agricultural Sciences, Department of Economics

ISSN 1401-4068
ISRN SLU-EKON-WPS-1302-SE

Working Paper Series 2013:02
Uppsala 2012

Corresponding author:
ing-marie.gren@slu.se

Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Department of Economics

Market power and double-dipping in nutrient trading markets

Abstract. Heavy loads of nutrients, i.e. nitrogen and phosphorus, cause severe damages in many waters in the world. This paper develops a model for nutrient trading markets for a sea damaged by both nitrogen and phosphorus and faces a dominant polluter of one or both nutrients. The existence of abatement measures with simultaneous impacts on both nutrients raises the need for double-dipping in both markets. It is shown that double-dipping decreases overall abatement costs for reaching predetermined targets, and reduces efficiency losses of market power, in particular when the same agent exercises market power in both markets. An empirical application to the intergovernmental agreement on reducing nutrient loads to the eutrophied Baltic Sea in North-East Europe demonstrates cost savings of approximately 25% from introduction of double-dipping, and that efficiency losses from market power of one dominant country, Poland, can be reduced by 10%.

Key words; nutrient trading, market power, double-dipping, eutrophication, Baltic Sea

JEL; L19, Q53, Q58

Department of Economics
Swedish University of Agricultural Sciences (SLU)
P.O. Box 7013, SE-750 07 Uppsala, Sweden
Ph. +46 18 6710 00, Fax+ 46 18 67 35 02
www.slu.se
www.slu.se/economics

Institutionen för ekonomi
Sveriges lantbruksuniversitet
Box 7013, 750 07 Uppsala
Tel. 018-67 10 00, fax 018 67 35 02
www.slu.se
www.slu.se/ekonomi

1. Introduction

Since early 1950s global nitrogen loads to coastal water have been doubled and phosphorus loads have been tripled (Selman et al*.,* 2008). These increases have created the documented raise in number of eutrophied coastal zones from 10 hypoxic areas in early 1960's to at least 169 in 2007 (Selman et al., 2008). Damages from eutrophication are oxygen depletion, occurrences of harmful algal blooms, and changes in composition of fish species at the disadvantage of commercial species. For example, excess blooms of a toxin-producing flagellate killed large numbers of fish in the Baltic Sea and Atlantic coast of the USA (Rosenberg et al., 1988; Burkholder and Glasgow, 1997), and one event of algal blooms destroyed 90% of the fish population in farms in Hongkong (Selman et al., 2008). Estimates of partial damage cost of eutrophication show that incomes losses can be substantial in anchovy fishery in the Black Sea (Knowler et al., 2001; Knowler and Barbier, 2005), and in North Carolina's brown shrimp fishery (Huang et al., 2012). Other studies indicate that people are willing to pay significant amounts, up to 10% of their annual income, to restore a eutrophied sea (e.g. Huang, 1997; Söderquist, 1998; Remoundou et al., 2009).

These manifestations of eutrophication have been recognized in practice which has been revealed by the implementation of a variety of policy instruments affecting nutrient loads to water courses (OECD, 2007). Nutrient trading market was identified as a promising instrument already in the 1960s, and has been implemented for controlling nitrogen or phosphorus in a large number of drainage basins, mainly in the US but also in Australia and China (Kraemer et al., 2004; SEPA, 2008). However, eutrophication management requires control of both nitrogen and phosphorus since damages are caused by unbalanced loads in these nutrients (e.g. Diaz and Rosenberg, 2008). This feature calls for instruments that allow for double-dipping in both markets when abatement measures exist that simultaneously affect both nutrients. That is, if an abatement measure reduces both nitrogen and phosphorus it should be considered in both nutrient markets.

Examples of double-acting measures are construction of wetlands as nutrient traps and reduction of livestock holdings which reduce both nitrogen and phosphorus. Another feature of eutrophication management is the potential existence of a dominating emission source, such as a large country in the catchment of an international sea like the North Sea or Baltic Sea. This may give rise to inefficiencies caused by the exercise of market power. The purpose of this study is to analyse the role of double-dipping for the functioning of nutrient trading markets, nitrogen and phosphorus, with market power in one or both markets. The model is applied to the Baltic Sea, which has been subject to long term monitoring and modelling generating necessary data for the empirical application (e.g. Savchuck and Wulff, 2009; Gren et al., 2008).

Starting in mid 1960s there is today a large body of literature on emission trading for improving water quality (e.g. Dales, 1968; Shortle, 1990; Shortle and Horan, 2001; Horan et al., 2002; Byström et al., 2000; Lukanski et al., 2008; Shortle and Horan 2008; Elofsson, 2010; Prabodanie et al. 2010). This can be traced to Coase (1960) who was among the first to suggest a market mechanism for negative externalities. A specific challenge of the design of water quality trading is the heterogeneity and uncertainty with respect to impacts on water recipients from different point and non-point emission sources. Several studies have also demonstrated the difficulties of achieving benefits from trade with heterogeneous polluters and several coupled water receptors (e.g. Prabodanie et al. 2010). With many receptors, agents have to trade at several markets, and trading ratios are required due to the different impacts on the receptors among point and non-point source polluters.

However, this paper will disregard the challenges imposed by optimal design of a permit market for trading between point and non-sources within a drainage basin. Instead, the focus is on the design of nutrient markets for trading among drainage basins with discharges into a common water body such as a marine sea. he inclusion of market power and consideration of two nutrients makes this paper mostly related to two strains of the literature; market structure and permit trading, and double-dipping in markets for measures affecting several pollutants. The large body of literature on market power and emission trading was initiated by the seminal paper by Hahn (1984), who investigated the implication on cost effectiveness from exercise of market power. Since then developments have been made with respect to consideration of banking of permits during time (Liski and Montero, 2005), of market power also in the product market (Hintermann, 2011), of non-compliance (van Egteren and Weber, 1996), and of conditions for the development and exercise of market power (Lange, 2012). The implication of economics of scope in abatement for policy design has been analysed in several papers, where Beavis and Walker (1979) provides an early contribution on the efficient design of multiple pollution charges. Michaelis (1992) considers efficient charges with multiple stock pollutants. Montero (2001) investigates efficient design of multiple trading markets under incomplete enforcement, and Woodward (2011) establishes conditions for efficiency gains from double-dipping.

The main contribution of this paper is the simultaneous consideration of market power and double-dipping in multiple emission trading markets. A theoretical model is constructed with two main features; market power is modelled as a monopolist with a competitive fringe in each market (e.g. Xepapadeas, 1997) and economics of scope is represented as joint abatement costs (e.g. Baumol et al., 1988). The model is applied to nutrient trading for meeting international agreements on nutrient load targets for the eutrophied Baltic Sea (Helcom, 2007). Although there is a relatively large body of literature on cost effective nutrient reductions to an international sea (Ollikanien and Hokatukla, 2001; Elofsson 2010; Gren and Destouni, 2012) there is no study addressing nutrient trading markets, multifunctional abatement measures, and market power. Nutrient permit markets for the Baltic Sea have been evaluated by Elofsson (2010) but not under influence of market power and/or allowance for double-dipping.

The paper is organised as follows. First, the model for nutrient trading is presented. Next, data retrieval is described and empirical results are presented. The paper ends with a brief summary and some tentative conclusions.

2. A model of nutrient permits trading

Two markets are considered, one for each nutrient. The size of the markets, $\overline{M}^{E}$ for $E=N,P$ where N is nitrogen and P is phosphorus, are assumed to be determined by restrictions on nutrient loads for achieving ecological conditions, such as the intergovernmental agreement on the Baltic Sea Action Plan (Helcom, 2007). Following Xepapadeas (1997) market structure is modelled as a monopoly with one dominating emission source and a competitive fringe. The $f=1,..,n$ actors on the markets are thus divided among the monopolist, actor 1, and the fringe consisting of the remaining actors, $f=2,..,n$. Nutrient loads in each country are determined by business as usual load (BAU), $L^{Ef'}$, minus abatement, R^{Ef}, which is written as $L^{Ef}=L^{Ef'} - R^{Ef}$. Total loads of nutrient are limited by the market size, i.e. $L^{E1} + \sum_{f=2}^{n} L^{Ef} \leq \overline{M}^{E}$.

For each country, the cost of abatement is described by the function $C^{f} = C^{f}(R^{Nf}, R^{Pf})$. Multifunctional abatement technologies give rise to economies of scope, which are defined as $C^{f}(R^{Nf}*, R^{Pf}*) < \sum_{E} C^{f}(R^{Ef}*)$. That is, the cost of joint abatement of certain amounts of nitrogen and phosphorus is lower than the sum of costs of separate abatement by the same amount of each nutrient (e.g Panzar and Willig, 1981; Baumol et al., 1988). Differentiation of the cost function with respect to each nutrient gives the marginal abatement cost of nitrogen as $C^{f}_{R^{fN}} = C^{f}_{R^{fN}}(R^{fN}, R^{fP})$ and that of phosphorus as $C^{f}_{R^{fP}} = C^{f}_{R^{fP}}(R^{fN}, R^{fP})$, with the second derivatives $C^{f}_{R^{fP}R^{fP}} > 0$, $C^{f}_{R^{fN}R^{fN}} > 0$, $C^{f}_{R^{fN}R^{fP}} < 0$, and $C^{f}_{R^{fP}R^{fN}} < 0$.

Given a certain initial allocation of permits, $\overline{M}^{Ef}$, and prices of nutrient permits, p^{E}, a country in the competitive fringe minimises total cost of abatement and permit purchases according to

$$\underset{R^{fN}, R^{fP}}{Min} \quad C^f(R^{fN}, R^{fP}) + p^N(L^{fN}{'} - R^{Nf} - \overline{M}^{fN}) + p^P(L^{fP'} - R^{Pf} - \overline{M}^{fP}) \qquad (1)$$

and associated first-order conditions are

$$C^f_{R^{fN}} - p^N = 0 \qquad (2)$$
$$C^f_{R^{fP}} - p^P = 0$$

For an interior solution, eq. (2) states that marginal abatement cost equals the permit price. It is shown in Appendix A that abatement of both nutrients is increasing in each of the nutrient prices, which results from the properties of the cost function. Under a single market system, i.e. when double-dipping is not allowed, abatement is increasing only in the own price.

The monopolist minimises total cost for abatement and permit trading similarly to the country in the competitive fringe as described by eq. (1). The difference is the monopolist's impact on equilibrating permit prices, which is determined by the competitive fringe's demand for nutrient permits. The fringe's demand for permits is derived from each country's optimal allocation of abatement measures for different levels of abatement, R^{Ef*}, as described by eq. (2). This condition determines the optimal abatement and, hence, demand for permits as a function of the nutrient permit prices, which gives the optimal nutrient load as $L^{Ef*} = L^{Ef}{'} - R^{Ef*}(p^N, p^P)$. The competitive fringe's demand for permit of one nutrient, say nitrogen, is then the sum of all countries' demand at different levels of the permit price, which is defined as $L^N = L^N(p^N, p^P)$. As shown in Appendix A, abatement of each nutrient is increasing in both nutrient prices. That is, an increase(decrease) in price of one nutrient reduces(increases) demand for permits in both markets since the increased(decreased) abatement associated with the price increase(decrease) results in simultaneous changes in abatement of both nutrients. The corresponding inverted demand functions are the fringe's marginal abatement cost functions for nutrients which show the demand for permits at different prices of nutrients, which are described as $p^E = p^E(L^E, L^{-E})$ where –*E* is the other nutrient.

Given the competitive fringe's inverted demand functions for nutrient permits, the decision problem of the monopolist is specified as the minimisation of total costs subject to market clearing conditions. The market clearing condition requires that the monopolist's supply of nutrient equals the competitive fringe's demand, i.e. that $\overline{M}^{E1} - L^{E1} = \sum_{f=2} L^{Ef} - \overline{M}^{Ef}$ for each nutrient. The monopolist decision problem is then written as

$$\min_{R^{N1}, R^{P1}} \quad C^1(R^{N1}, R^{P1}) + p^N(L^N, L^P)(L^{N1}{'} - R^{N1} - \overline{M}^{N1}) + p^P(L^N, L^P)(L^{P1'} - R^{P1} - \overline{M}^{P1}) \tag{3}$$

s.t

$$\overline{M}^E = L^{E1}{'} - \sum_i R^{E1}(A^{i1}) + L^E \quad for\ E = N, P$$

Noting that $L^E = \overline{M}^E - L^{E1}{'} + R^{E1}$, the first-order conditions for the monopolist when double-dipping is allowed are delivered as

$$C^1_{R^{N1}} - p^N + p^N_{R^{N1}}(L^{N1}{'} - R^{N1} - \overline{M}^{N1}) + p^P_{R^{N1}}(L^{P1}{'} - R^{P1} - \overline{M}^{P1}) = 0 \tag{4}$$

$$C^1_{R^{P1}} - p^P + p^P_{R^{P1}}(L^{P1}{'} - R^{P1} - \overline{M}^{P1}) + p^N_{R^{P1}}(L^{N1}{'} - R^{N1} - \overline{M}^{N1}) = 0 \tag{5}$$

According to eqs. (4)-(5) the monopolist abates where the marginal abatement cost of a nutrient equals marginal benefit. The first terms at the left hand side of (4)-(5) constitute the marginal abatement costs. The remaining terms express the marginal benefits which include the permit price, the monopolist's adjustment of the own price, and the effect on the demand for the other nutrient. In order to capture the monopoly profit, a monopolist increases the permit price by reducing abatement and making use of more permits which decreases the supply of permits. This is shown by the third term at the left hand sides, which is positive since $p^{E}_{R^{E1}} < 0$ and $L^{E1}{'} - R^{E1} - \overline{M}^{E1} < 0$. The competitive fringe responds by reducing its demand for that nutrient. Due to complementarity in abatement there is a simultaneous decrease in demand for the other nutrient with an associated decrease in permit price. This is shown by the fourth terms at the LHS which are negative since $p^{-E}_{R^{E1}} > 0$ and $L^{-E1}{'} - R^{-E1} - \overline{M}^{-E1} < 0$. The cross price effects thus mitigate the increase in the own price from withholding permits. The magnitude of the impact depends on the cross price effect, and on the initial allocation of permits to the monopolist.

When the country acts as a monopolist on only one market and there is competitive conditions on the other, one of the first order conditions in (4)-(5) is replaced by the corresponding condition in eq. (2). The counteracting impact of monopoly power in, say nitrogen market, still occurs as a decrease in the competitive fringe's demand for phosphorus when the monopoly reduces supply of the nitrogen in order to raise the price. However, the mitigation effect is decreased since the price of phosphorus is given by the competitive market, and there is thus no consideration of the impact of this price on that of nitrogen. When double-dipping is not allowed, and market power prevails in both markets, the condition for optimality is $C^{1}_{R^{E1}} - p^{N} + p^{E}_{R^{N1}}(L^{E1}{'} - R^{E1} - \overline{M}^{E1}) = 0$ for *E=N,P*. The distortion of market power is thus largest under separate markets since there are no counteracting effects from the monopolist's consideration of its effects of actions on one nutrient market on the other nutrient market.

As demonstrated in several papers, the market power distortion can also be effected by the distribution of initial permits (e.g. Xepapadeas, 1997). The smaller allocation of initial permits to the monopolist, the lower is the monopoly equilibrium permit price. It is shown in Appendix A that R^{E1} is decreasing, and, hence, p^{E} increasing, in $\overline{M}^{E1}$ also when double dipping is allowed, and that this effect is reduced by the cross price effects. An increase in the initial allocation of permits to the monopolist of nutrient E raises the equilibrium price of this nutrient. This, in turn, increases the fringe's abatement of both nutrients, which reduces the demand for the other nutrient and the associated equilibrium permit price. When there is monopoly power in only one market, say nitrogen, an increase in initial permits of nitrogen raises the equilibrium price, while an increase in the allocation of phosphorus permits has the opposite effects (see Appendix A). A larger number of permits of phosphorus increase the losses from reduced demand for this nutrient due to monopoly price of nitrogen (shown by the fourth term at the left hand side of (4)) and, hence, creates incentives to reduce the price of nitrogen. Thus, efficiency losses from market power can be mitigated, not only by reducing initial allocation of permits on that market, but also by increasing distribution of initial permits on the competitive market when double-dipping is allowed.

3. Application to the Baltic Sea

The Baltic Sea has been reported to contain the largest anthropogenic dead zone in the world (Diaz and Rosenberg, 2008) and the effects of eutrophication in this system have been well described (Elmgren and Larsson, 2001; Conley et al., 2009). The catchment of the sea inhabits a population of 85 million in the nine riparian countries (see Figure C1 in Appendix C for a map). Mitigation of the damage from eutrophication has been on the agenda for the riparian countries for decades, leading to the collaborative establishment of the Convention on the Protection of the Marine Environment of the Baltic Sea (Helsinki Commission HELCOM) in the late 1980s, working to monitor the status of the sea and to implement reduction targets for anthropogenic nutrient emissions and discharges (Backer and Leppänen, 2008). The long term concern of the Baltic Sea has also resulted in a relatively good access of data on nutrient abatement costs for the nine riparian countries.

3.1 Data retrieval

Data on annual nutrient loads and abatement costs are obtained from Gren et al. (2008). Estimated nutrient loads from the nine riparian countries are presented in Table 1, where it is shown that Poland accounts for 57% of total phosphorus load and for 39% of total nitrogen load.

Table 1: Nutrient load to theBaltic Sea from the riparian countries, thousand tons in 2005

	Nitrogen		***Phosphorus***	
	Kton	***Share of total***	***Kton***	***Share of total***
Denmark	44	0.05	1.1	0.03
Finland	49	0.06	1.7	0.04
Germany	46	0.06	0.5	0.01
Poland	318	0.39	22.0	0.57
Sweden	74	0.09	1.6	0.04
Estonia	56	0.07	1.6	0.04
Latvia	44	0.05	3.0	0.08
Lithuania	93	0.12	3.5	0.09
Russia	83	0.10	4.0	0.10
Total	*806*	1.00	*38.9*	1.00

Source: Gren et al. 2008, table 1 page 13

Since Poland is dominating with respect to loads of, in particular, phosphorus this country is treated as a monopolist and the rest of the countries as a competitive fringe. The static cost minimisation model in Gren et al (2008) is used for obtaining cost minimising solutions with and without market power, and for deriving the competitive fringe's inverted demand functions for both nutrients.

The mathematical programming model in Gren et al. (2008) includes 13 different measures for nitrogen reductions and 11 abatement measures for phosphorous reductions in each drainage basin (see map in Figure C1 Appendix C). The included abatement measures affecting only one nutrient are: increased nutrient cleaning capacity at sewage treatment plants, catalysts in cars and ships, flue gas cleaning in stationary combustion sources, and reductions in the agricultural deposition of fertilisers. Measures affecting both nutrient loads are livestock reduction, change in spreading time of manure from autumn to spring, cultivation of so called catch crops, energy forests, ley grass, and creation of wetlands. A change of spreading time from autumn to spring implies less leaching since, in spring, there is a growing crop which utilises the nutrients. Catch crops refer to certain grass crops, which are drilled at the same time as the ordinary spring crop but the growth, and thereby the use of remaining nutrients in the soil, is concentrated to the period subsequent to the ordinary crop harvest. Nutrient abatement cost estimates for sewage treatment plants, fertiliser reductions, reduction in nitrogen oxides from reduced use of fossil fuel and are based on econometric estimates with cross section data. Costs of measures changing land use include opportunity cost of land and management costs. Abatement costs of all other measures are obtained from enterprise budgets.

Each abatement measure is also subject to capacity constraint, such as a maximum possible phosphorus removal at sewage treatment plants by 90 per cent. Additional constraints consist of the number of households that can be connected to sewage treatment plants. Limitations on fertiliser and livestock reductions and land use changes are imposed in order to avoid drastic structural changes in the agricultural sector. For a more detailed presentation of abatement capacities and costs of all measures, see Gren et al. (2008).

A pseudo data approach is applied for estimating the inverted demand functions for nutrients, where data are generated from the Gren et al., (2008) static programming model (see e.g. Griffin, 1978 for discussion of the pseudo data approach). This is made in two steps. First, a cost function for nutrient abatement is estimated for the competitive fringe. Second, the cost function is differentiated with respect to each nutrient which gives the corresponding marginal cost functions, and, hence, demand functions for permits. Monte Carlo simulations are carried out for obtaining data on costs for 500 random combinations of N and P reductions. Minimum costs are estimated for each combination, which results in 500 observations, see Appendix B for descriptive statistics and results from regression estimates of a quadratic cost functions using ordinary least square estimates.

In the second step, price functions are obtained by differentiating the estimated cost functions with respect to competitive fringe's nitrogen and phosphorus loads. Observing that the fringe's load is determined by the sizes of the markets and the Polish loads as shown in eq. (3), the inverted demand functions can be written as

$$p^N = 632 - 1.41(\overline{M}^{N1} - L^{N1}{}' + R^{N1}) + 3.85(\overline{M}^{P1} - L^{P1'} + R^{P1}) \quad (6)$$

$$p^P = 6169 - 602(\overline{M}^{P1} - L^{P1'} + R^{P1}) + 3.85(\overline{M}^{N1} - L^{N1'} + R^{N1}) \quad (7)$$

The own price effects are shown by the coefficients of the second term at the right hand side of equations (6)-(7), and the cross price effects by coefficient of the third.

Finally, there is a need for defining the size of the market for each nutrient. This is determined by the targets set by the intergovernmental agreement, the Baltic Sea Action Plan (BSAP) (Helcom, 2007). BSAP sets for the seven different marine basins in the Baltic Sea depending on their ecological status. In principle, this would require markets for each of the seven marine basins. However, as shown in Gren et al. (2012) the achievement of the target in the largest basin, Baltic Proper, generates required target achievements also in the other marine basins. The reasons are the relative stringent nutrient reduction targets for this basin, and the high interconnectedness with other marine basins. A simplification is therefore made in this numerical demonstration by considering only one market for each nutrient the size of which is determined by the requirements of the Baltic Proper, which implies nutrient loads corresponding to 35%t of BAU phosphorus load and 70% of BAU nitrogen load.

3.2 Results

Calculations are made for single and multi markets, operating under competitive conditions and monopoly power. Double-dipping is allowed in the multi markets settings. The GAMS code with the Conopt2 solver is used for solving the problem (Brooke et al. 1998). Total abatement cost under two markets structures – competitive and monopoly – and two market designs, single and multi nutrient markets, are shown in Figure 1. Further, results are presented for two alternative allocations of initial permits under the monopoly case; one where permits are allocated with equal proportions, which correspond to the share of the market in relation to BAU loads, for each country, and one where Poland receives all permits. This means that this country receives more permits to emit nitrogen than its actual loads. Although this seems unrealistic it can be of interest to note the distribution of carbon dioxide emission permits in excess of actual emissions to Russia under the Kyoto protocol. The country was essential for a legally binding international agreement on carbon dioxide reductions. Similarly, without Polish commitments, it will not be possible to achieve the nutrient targets in BSAP. An allocation where Poland receives all permits also gives information on the maximum effects of market power.

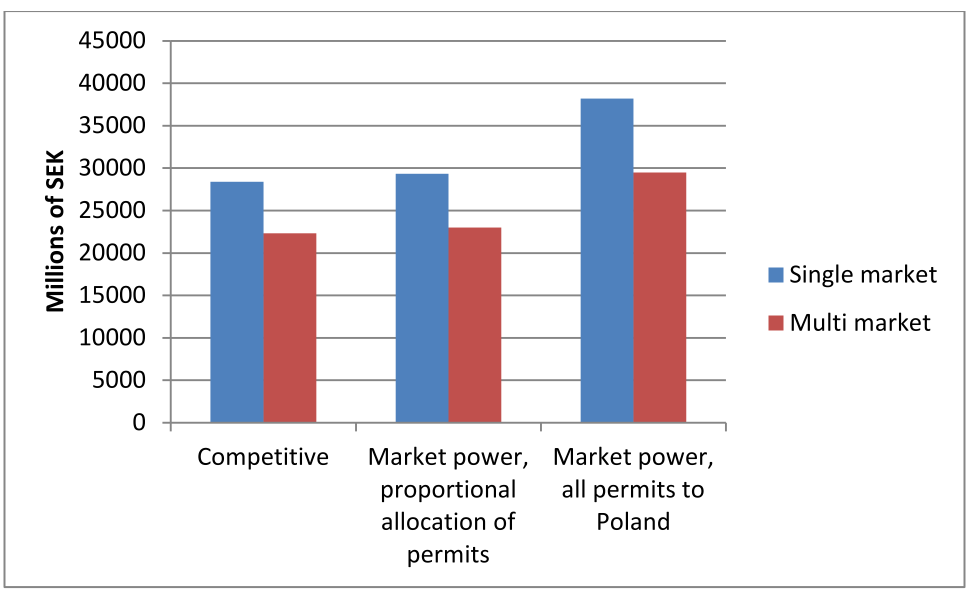

Figure 1: Total abatement costs for single and multi nutrient trading markets under competitive and monopoly market structures. (1 Euro = 8.61 SEK, Nov. 25 2012)

The results in Figure 1 reveal that total abetment cost under competitive market is approximately 25% lower under multi than single markets. The total costs under competitive market structure come close to the only two other studies calculating costs of the BSAP agreement; Gren and Destouni (2012) and Elofsson (2010). Gren and Destouni (2012) obtain estimates for multi markets that vary between 18 and 25 billions of SEK (1 Euro = 8.61 SEK Nov. 25, 2012) depending on assumptions of measured BAU nutrient loads in the drainage basins. Elofsson's (2010) estimates of costs for single markets amount to approximately 30 billions of SEK, which is slightly higher than our estimate of 28 billions of SEK.

Under competitive conditions and single nutrient trading markets, approximately 2/3 of total costs are attributed to reaching the reduction target of phosphorus, see Table 2. The reason is the relatively high stringency of the phosphorus target.

Table 2: Abatement costs and equilibrating permit price under single and multi markets without market power

	Abatement cost, Mill SEK[1]:			***Equilibrating prices, SEK[1]/kg:***	
	N	***P***	***Total***	***N***	***P***
Separate markets:				67	2308
Poland	3225	11495	14720		
Fringe	4193	9891	14084		
Total	7418	21386	28804		
Double dipping				51	2106
Poland			14284		
Fringe			8991		
Total			23275		

1) 1 Euro = 8.61 SEK, Nov. 25 2012

Under multi markets the total cost is slightly larger than that for achieving the phosphorus target under single markets. The impact on costs of a move from single to multi markets is also shown by the change in equilibrating market prices; the price of nitrogen decreases by 25% and that of phosphorus by 9%. The relatively large decrease in the nitrogen price is due to the impact on nitrogen loads from multifunctional measures implemented in the cost effective solution for reaching the higher phosphorus target. Common to both single and multi markets is the relatively equal sharing of total costs between the fringe and Poland.

Efficiency losses from market power correspond, at the most, to 35% of the cost under competitive conditions, which occur for single markets and when Poland receives all permits. Corresponding efficiency losses with multi markets are 32%. It can be noticed that the efficiency losses are modest when initial permits are distributed with the same proportion of initial loads to each country. They correspond to approximately 3.3% and 3% under single and multi markets respectively. When comparing these results with the few existing empirical studies, which rely on laboratory experiments, it can be noticed that they are in line with Bohm and Carlen (1999) but in contrast to those obtained by Godby (2002). This can be explained by different assumptions with respect to means and sizes of initial distribution of permits. As shown by Lange (2012), relative disturbance of market power is positively related to the size of initial permits and to the number of actors in the market.

Since the efficiency losses of monopoly power are quite modest when initial permits are distributed in proportion to initial use, effects of monopoly power on abatement costs and prices are presented only for the case when all permits of nitrogen and phosphorus are distributed to Poland, see Table 3.

Table 3: Abatement costs and permit prices in single and multi markets with monopoly power by Poland.

	Abatement cost, Mill SEK[1]: ***N***	***P***	***Total***	***Equilibrating prices, SEK[1]/kg:*** ***N***	***P***
Single markets:				124	2758
Poland	45	6383	6428		
Fringe	14510	15712	30222		
Total	14555	23676	38231		
Multi markets;				104	2376
Poland			7984		
Fringe			21533		
Total			29517		

1) 1 Euro = 8.61 SEK, Nov. 25, 2012

As expected, abatement costs are lower for Poland under monopoly power compared with competitive conditions. Under single markets, the largest gain from monopoly power is obtained from the nitrogen market, which is explained by the large allocation of permits to Poland and the low abatement cost. The equilibrium price of nitrogen permits is almost doubled, from SEK 67/kg N in the competitive market to SEK 124/kg under monopoly. The increase in price of phosphorus permits is smaller, approximately 20% from that in the competitive market. Total abatement cost decreases by about 1/3 when double-dipping is allowed, abatement costs increase for Poland and the equilibrium prices of both nutrients decrease.

When Poland exercises monopoly power in only one nutrient trading market, the increase in corresponding equilibrium price is higher than with market power in both markets, which is expected from the theoretical analyses in Section 2. Under monopoly power in the nitrogen market, the price of SEK 106/kg N is slightly higher than when monopoly power is exercised in both markets, see Table C1 in appendix C. Similarly, the equilibrating price of phosphorus under market power for this nutrient is SEK 2516/kg P, which is slightly above the price of 2470/kg P with market power in both markets.

4. Conclusions and discussion

The purpose of this paper has been to analyse the impact of monopoly power and double-dipping in two nutrient trading markets for a eutrophied sea. The need of reducing both nutrient loads to a eutrophied seas and the existence of abatement measures affecting both nitrogen and phosphorus load raise the question whether double-dipping in both nutrient markets should be allowed. By constructing a model with a monopolist and competitive fringe on one or both markets for nutrient permits it was shown that double-dipping reduces the efficiency losses of market power. The reason is that the monopolist needs to consider the price effects on both markets when determining optimal supply of permits on one market. A decrease in supply of permits in one market in order to raise the equilibrium price forces the competitive fringe to increase abatement of that nutrient which gives a simultaneous reduction in the other nutrient. This reduces the demand for and hence the equilibrium permit price of that nutrient. Thus, by allowing for double-dipping distortions of market power could be mitigated. It was also shown that when market power prevails in one market but not in the other, the monopoly equilibrium price increases compared to when there is market power in both markets. Another theoretical result revealed that increases in the allocation of initial permits to the monopolist aggravate the distortion, but that double-dipping mitigate this effect compared with single markets. However, when there is market power in only one market, an increase in allocation of permits to the monopolist of the nutrient traded on the competitive market curbs efficiency losses of monopoly power.

The empirical application to the Baltic Sea showed that total abatement costs for achieving the intergovernmental agreement set by Helcom (2007) can be reduced by approximately 25% if double-dipping is allowed and both nutrient markets are competitive. In this application one country, Poland, with major loads of both nutrients was treated as a monopolist and the remaining eight countries as a competitive fringe. Efficiency losses from market power turned out to be quite modest when the initial permits are distributed in proportion to business as usual loads to each country. The market share of Poland is then too small to give large monopoly gains. These gains are increased when Poland receives all permits, and can increase total abatement costs for meeting nutrient reduction targets by approximately 35% compared to a competitive market. A move from single to multi-market can then decrease total abatement costs by 25%.

Markets for nutrient trading in the Baltic Sea have been suggested by NEFCO (2008), and the introduction of these might benefit from experiences gained from the EU emission trading system (ETS) for carbon dioxides. On the other hand, the EU ETS market does not include land use measures, which are crucial for nutrient abatement. Instead, multifunctional land uses promoting several positive externalities have been supported by subsidy systems within the EU common agricultural policy and by national initiatives (see Nilsson et al. 2008 for a review). The introduction of nutrient trading markets for the Baltic Sea would thus require a change compared to current EU ETS system and to common subsidy practices in several EU countries.

The relative advantages of trading markets compared to subsidy systems with respect to cost effectiveness are well established in the literature (e.g. Baumol and Oates, 1988). However, the establishment of several markets and allowing for double-dipping may be prevented by the requirement of additionality. In principle, additionality is defined by an activity which produces 'extra good' relative to a baseline scenario. This principle is of vital importance for projects under the clean development mechanism under the Kyoto protocol, which allows for offsetting credits in the EU ETS. Under single nutrient trading markets, abatement measures are implemented under either of the markets depending on marginal abatement cost and the equilibrium permit price. This will generate reductions in both nutrients when multifunctional measures have relative cost advantages in one of the nutrient trading markets. The choice of base line is then crucial; if it refers to nutrient loads without any policy in a specific point of time, or if it refers to the difference in nutrient loads compared to business as usual loads. The former baseline principle is adopted in the EU climate change policy which sets national plans for carbon dioxide reduction compared with emissions in 1990. Such a baseline has been implicitly assumed in this paper, since it allows for nutrient credits in both markets irrespective of the origins of the nutrient load reduction. Under a business as usual baseline, additionality is much more difficult to establish since nutrient load reductions obtained in one market do not allow for credits in the other market. Such as baseline system would change the results obtained in this paper, and reduce the gains from double-dipping since the nutrient load credits obtained in the complementary market are decreased.

Appendix A: Derivation of impacts of prices and initial allocations of permits on optimal abatement

Applying the implicit function theorem on the first order conditions expressed by eq. (2), the Hessian matrix, H, and determinant are obtained as

$$H^C = \begin{vmatrix} C^f_{R^N R^N} & C^f_{R^N R^P} \\ C^f_{R^P R^N} & C^f_{R^P R^P} \end{vmatrix} = C^f_{R^N R^N} C^f_{R^P R^P} - C^f_{R^N R^P} C^f_{R^P R^N} > 0 \qquad \text{(A1)}$$

where sub-indexes are second derivatives. Solving for the impact of a nitrogen price change on abatement of phosphorus, i.e. $R^{fP}_{P^N}$, gives

$$R^{fP}_{P^N} = \frac{-C^f_{R^P R^N}}{C^f_{R^N R^N} C^f_{R^P R^P} - C^f_{R^N R^P} C^f_{R^P R^N}} > 0 \qquad (A2)$$

The Hessian matrix under monopoly, H^M, is obtained from the first-order conditions (4)-(5) as

$$H^M = \qquad (A3)$$

$$\begin{vmatrix} C^1_{R^{N1}R^{N1}} - 2p^N_{R^{N1}} + p^N_{R^{N1}R^{N1}} G^{N1} + p^P_{R^{N1}R^{N1}} G^{P1} & C^1_{R^{N1}R^{P1}} - p^N_{R^{P1}} + p^P_{R^{N1}R^{P1}} G^{N1} - p^P_{R^{N1}} + p^P_{R^{N1}R^{P1}} G^{P1} \\ C^1_{R^{P1}R^{N1}} - p^N_{R^{N1}} + p^N_{R^{N1}R^{N1}} G^{N1} - p^P_{R^{N1}} + p^P_{R^{P1}R^{N1}} G^{P1} & C^1_{R^{P1}R^{P1}} + p^N_{R^{N1}R^{P1}} G^{N1} - 2p^P_{R^{P1}} + p^P_{R^{P1}R^{P1}} G^{P1} \end{vmatrix} > 0$$

where $G^{N1} = (L^{N1} - R^{N1} - \overline{M}^{N1})$ and $G^{P1} = (L^{P1} - R^{P1} - \overline{M}^{P1})$. Simplifying (A3) by assuming linear price functions where the second derivatives do not exist, the impact of changes in $\overline{M}^{N1}$ and $\overline{M}^{P1}$ on $R^{N1}*$ and $R^{P1}*$ are found as

$$R^{N1}_{\overline{M}^{N1}} = \frac{p^{N1}_{R^{N1}}(C^{1}_{R^{P1}R^{P1}} - 2p^{P}_{R^{P1}}) - p^{P}_{R^{N1}}(C^{1}_{R^{P1}R^{P1}} - p^{N}_{R^{P1}} - p^{P}_{R^{N1}})}{H^{M}} < 0 \qquad (A4)$$

$$if \;\; p^{N1}_{R^{N1}}(C^{1}_{R^{N1}R^{N1}} - 2p^{N}_{R^{N1}}) < -p^{P}_{R^{N1}}(C^{1}_{R^{N1}R^{P1}} - p^{N}_{R^{P1}} - p^{P}_{R^{N1}})$$

The denominator of (A4) contains two counteracting factors; the decrease in abatement in order to raise the own price (the first expression in the denominator of (A4)) and the associated loss in profits from a decrease in demand for phosphorus permits (the second expression). Without cross effect between the nutrients, the decrease in $R^{N1}*$ and hence increase in p^{N} would be larger since denominator would be higher and the numerator lower. In a similar vein $R^{P1}_{\overline{M}^{N1}}$ is obtained as

$$R^{P1}_{\overline{M}^{N1}} = \frac{p^{P1}_{R^{P1}}(C^{1}_{R^{N1}R^{N1}} - 2p^{N}_{R^{N1}}) - p^{P}_{R^{P1}}(C^{1}_{R^{P1}R^{NP1}} - p^{N}_{R^{N1}} - p^{P}_{R^{N1}})}{H^{M}} < 0 \qquad (A5)$$

$$if \;\; p^{P1}_{R^{P1}}(C^{1}_{R^{N1}R^{N1}} - 2p^{N}_{R^{N1}}) < -p^{P}_{R^{P1}}(C^{1}_{R^{P1}R^{NP1}} - p^{N}_{R^{N1}} - p^{P}_{R^{N1}})$$

When only one market, say nitrogen trading, is subject to market power, the corresponding Hessian, H^{MN}, is defined by

$$H^{MN} = \begin{vmatrix} C^{1}_{R^{N1}R^{N1}} - 2p^{N}_{R^{N1}} & C^{1}_{R^{N1}R^{P1}} \\ C^{1}_{R^{P1}R^{N1}} - p^{N}_{R^{N1}} - p^{P}_{R^{N1}} & C^{1}_{R^{P1}R^{P1}} \end{vmatrix} > 0 \qquad (A6)$$

Solving for $R^{N1}_{\overline{M}^{N1}}$ and $R^{1}_{\overline{M}^{P1}}$ deliver

$$R^{N1}_{\overline{M}^{N1}} = \frac{p^{N}_{R^{N1}} C_{R^{P1}R^{P1}}}{H^{MN}} < 0 \qquad (A7)$$

$$R^{N1}_{M^{P1}} = \frac{p^{P}_{R^{N1}} C_{R^{N1}R^{N1}}}{H^{MN}} > 0 \qquad (A8)$$

Appendix B: Estimation of abatement cost function for the competitive fringe

Descriptive statistics of costs of 500 random combinations of nitrogen and phosphorus loads are displayed in Table B1.

Table B1: Descriptive statistics of data for variables in the fringe's abatement cost function, n=500

Variable	*Mean*	*Standard deviation*	*Min value*	*Max value*
Costs, mill SEK[1]	19827	16789	65	89090
Nitrogen load, kton N	394	105	201	563
Phosphorus load, kton P	9.6	3.7	3.2	16.0

1) 1 Euro = 8.61 SEK Nov. 12, 2012

Ordinary least square estimator is used to regress the estimated minimum cost as a quadratic function of nitrogen and phosphorus loads, see Table B2.

Table B2: Regression results

Independent variable, and test statistics	*Coefficient value*	*t-statistics*
N	-631.7	-28.66
P	-6169.6	-15.43
N^2	0.71	29.23
P^2	300.8	19.66
NP	-3.85	-6.42
F (5, 494)	1840	
Adj R^2	0.96	

The results show good statistical fit and does not reveal problems with heteroscedasticity

Appendix C: Figure C1 and Table C1

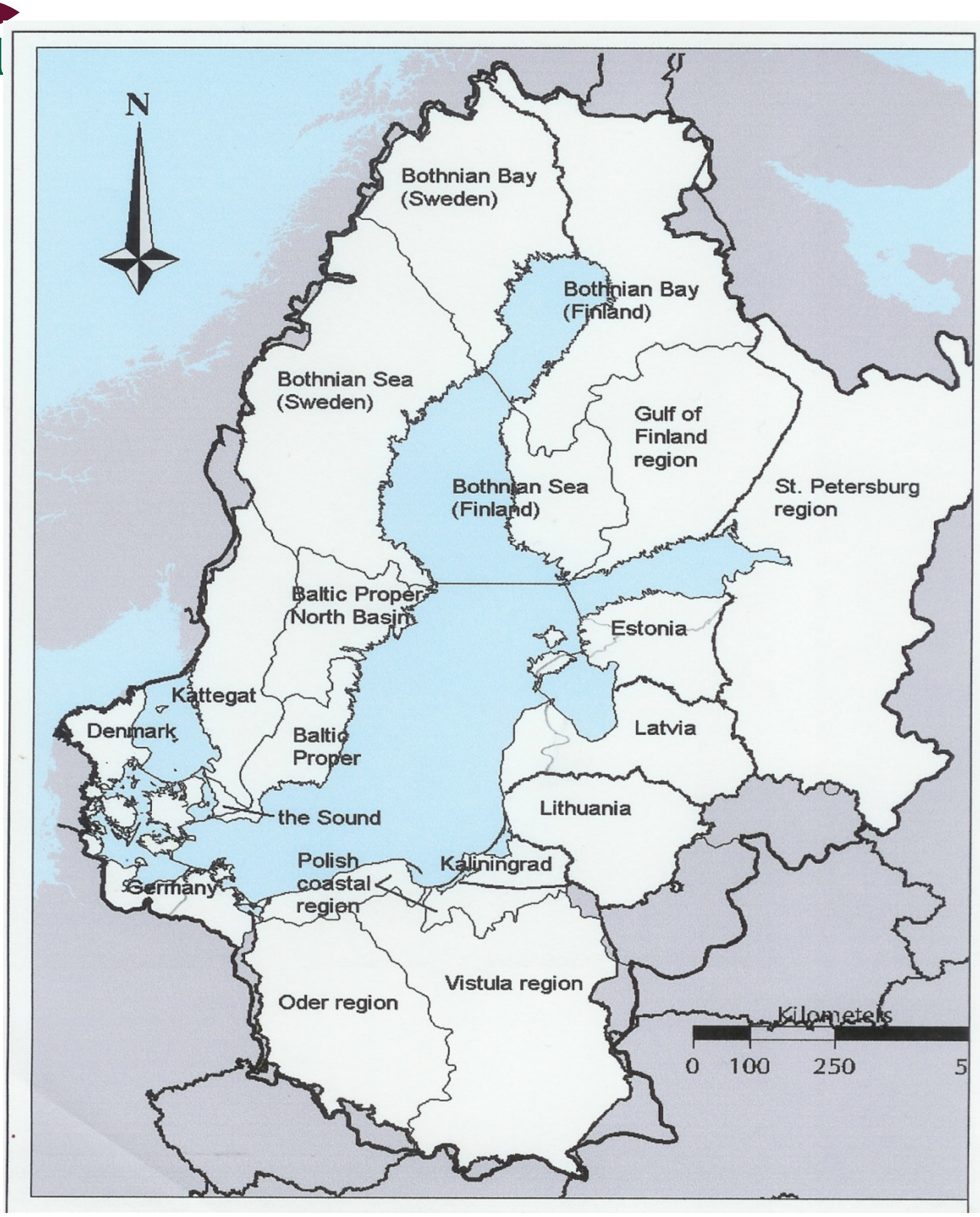

Figure C1: Drainage basins of the Baltic Sea (originally from Elofsson. 2003). (Drainage basins in Denmark (2). Germany (2). Latvia (2). and Estonia (3) are not provided with names but are delineated only by fine lines)

Table C1: Abatement costs and permit prices in multi markets with monopoly power by Poland in either nitrogen or phosphorus markets.

	Abatement cost, Mill SEK[1]	***Equilibrating prices, SEK[1]/kg:***	
		N	***P***
Monopoly power in N market;		106	2106
Poland	13338		
Fringe	16675		
Total	30013		
Monopoly power in P market;		51	2516
Poland	10209		
Fringe	13605		
Total	23814		

1) 1 Euro = 8.61 SEK Nov. 25, 2012

References

Backer, H., Leppänen, J.M., 2008. The HELCOM system of a vision, strategic goals and ecological objectives: implementing an ecosystem approach to the management of human activities in the Baltic Sea. Marine Freshwater Ecosystem. 18, 321-224.

Baumol, J.W., Oates, W.E., 1988. The theory of environmental policy. Cambridge University Press, UK.

Beavis, B., Walker, M., 1979. Interactive pollutants and joint abatement costs: achieving water quality standards with effluent charges. Journal of Environmental Economics and Management. 6(4), 275-286.

Bohm, P., Carlén, B., 1999. Emission quota trade among the few: laboratory evidence of joint implementation among committed countries. Resource and Energy Economics. 21(1), 43-66.

Brooke, A., Kendrick D., Meeraus A., 1998. Gams – a user's guide. San Francisco, The Scientific Press, USA.

Burkholder, J.M., Glasgow, H.B., 1997. *Pfiesteria piscicida* and other *Pfesteria*-like dinoflagellater: Behavior, impact and environmental control. Limnology and Ocenaography. 24, 26-36.

Byström, O., Andersson, H., Gren, I-M., 2000. Economic criteria for wetlands as nitrogen sinks. Ecological Economics. 35, 35-45.

Coase, R.H., 1960. The problem of social cost. Journal of Law and Economics. 3(1), 1-44.

Conley D.J., Björck S., Bonsdorff E., et al., 2009. Hypoxia-related processes in the Baltic Sea. Environmental Science and Technology. 43, 3412-3420.

Dales, J.H., 1968. Pollution, property and prices. Toronto, University of Toronto Press.

Díaz, R. J. Rosenberg, R., 2008. Spreading dead zones and consequences for marine ecosystems. Science. 321, 926-929.

Elmgren, R., Larsson, U. 2001. Europhication in the Baltic Sea area. Integrated coastal management issues. In: Bodugen, B. V. and R.K. Turner (eds.), Science and Integrated Coastal Management. Dahlem University Press, Berlin, pp. 15-35.

Elofsson, K., 2010. Cost-effectiveness of the Baltic Sea Action Plan. Marine Policy. 4(5), 1043-1050.

Godby, R., 2002. Market power in laboratory emission permits markets. Environmental and Resource Economics 23(3), 279-318.

Gren, I-M., Lindqvist, M., Jonzon, Y., 2008. Calculation of costs for nutrient reductions to the Baltic Sea – technical report. Working paper no. 1. Department of Economics, SLU, Uppsala.

Gren, I-M., Savchuck, O., Jansson, T. 2012. Cost effective dynamic and spatial management of a eutrophied sea with coupled heterogeneous marine basins. Marine Resource Economics, in revision.

Gren, I-M., Destouni, G., 2012. Does divergences in nutrient measurements matter for successful mitigation of marine eutrophication. Ambio. 41(2), 151-160.

Griffin, J.H., 1978. Joint production technology: the case of petrochemicals. Econometrica. 46(2), 379 – 396.

Hahn, R.W., 1984. Market power and transferable property rights. Quarterly Journal of Economics. 99(4), 753-765.

Helcom 2007. An approach to set country-wise nutrient reduction allocations to reach good marine environment of the Baltic Sea. Helcom BSAP Eutro Expo/2007. Helsinki Commission, Helsinki, Finland.

Hintermann, B., 2011. Market power, permit allocation and efficiency in emission permit markets. Environmental and Resource Economics. 49, 327-349.

Huang, J., Haab, C., Whitehead, J., 1997. Willingness to pay for quality improvement: should revealed and stated preferences data be combined? Journal of Environmental Economics and Management. 34(3), 240-255.

Huang, L., L.A.B. Nichols, J.K. Craig, Smith, M.D., 2012. Measuring welfare losses from hypoxia: the case of North Carolina brown shrimp. Marine Resource Economics. 27(1), 3-23.

Kraemer, R.A. Kampa, E., Interwies, E. 2004. The role of tradable permits in water pollution control. Inter-American Development Bank, Sustainable Development Department, Environment Division.

Knowler D., E.B. Barbier, Strand, I.E., 2001. An open-access model of fisheries and nutrient enrichment in the Black Sea. Marine Resource Economics. 16, 195-217.

Knowler, D., Barbier, E.B., 2005. Managing the Black Sea anchovery with nutrient enrichment and a biological invader. Marine Resource Economics. 20, 263-285.

Lange, A., 2012. On the endogeneity of market power in emission markets. Environmental and Resource Economics. 52, 573-583.

Liski, M., Montero, J-P., 2005. A note on market power in an emission permits market with banking. Environmental and Resource Economics. 31(2), 159-173.

Lukanski, J., Lichtenberg, E., Ollikainen, M., 2008. Point/nonpoint effluent trading with spatial heterogeneity. American Journal of Agricultural Economics. 90(4), 1004-1058

Montero, J-P., 2001. Multipollutant markets. Rand Journal of Economics. 32(4), 762-774.

NEFCO (Nordic Environment Finance Corporation) 2008. Framework for a nutrient quota and credit's trading system for the contracting parties of HELCOM to reduce eutrophication of the Baltic Sea. JR-080229-P5320-006, NEFCO, Helsinki, at http://www.nefco.org/files/Nefco_BS%20NTS_GSN_Final%20Report_20080229%20Summary.pdf (access date, November 20, 2012)

Nilsson, F.O.L., Hasund K.P., Gren, I-M., Surry, Y. 2008. Multifunctional agriculture – what does the literature tell us? International Review of Environmental and Resource Economics. 2(4), 281-319.

OECD. 2007. Instruments mixes addressing non-point source of water pollution. COM/EPOC/AGR/CA(2004)90/FINAL.

Ollikainen, M., Honkatukla, J. 2001. Towards efficient pollution control in the Baltic Sea: An anatomy of current failure with suggestions for change. Ambio. 30(4-5), 2001.

Panzar, J., Willig, R.,1981. Economies of scope. American Economic Review. 71(2), 268-274

Prabodanie, R., Raffensperger, J., Milke M., 2010 A pollution offset system for trading non-point source water pollution permits. Environmental and Resource Economics. 45(4), 499-515.

Remoundou, K., Koundouri, P., Kontogianni, A., Nunes, P., Skourtos, M., 2009. Valuation of natural marine ecosystems: an economic perspective. Environmental Science & Policy. 12, 1040-1051.

Rosenberg, R., Lindahl, O., Blanck, H. 1988. Silent spring in the sea. Ambio. 17(4), 289-290.

Savchuck, O. , Wulff, F., 2009. Long-term modelling of large-scale nutrient cycles in the entire Baltic Sea. Hydrobiologia. 629, 209-224.

Selman, M., Greenhalgh, S., Diaz, R., Sugg, Z., 2008. Eutrophication and hypoxia in coastal areas: a global assessment of the state of knowledge. WRI Policy Note 1, at http://pdf.wri.org/eutrophication_and_hypoxia_in_coastal_areas.pdf (access date August 5, 2012)

SEPA (Swedish Environmental Protection Agency) 2008. Suggestions for a charge system on nitrogen and phosphorus (in Swedish). Report 5913. Stockholm, Sweden.

Shortle, J.,1990. The allocative efficiency implications of water pollution abatement cost comparisons. Water Resources Research. 26, 793-797.

Shortle, J., Horan, R. 2001. The economics of non-point pollution control. Journal of Economic Surveys. 15(3), 255-290.

Söderquist, T., 1998. Why give up money for the Baltic Sea? Motives for peoples' willingness to pay. Environmental and Resource Economics. 12(2), 141-153.

Van Egteren, H., Weber, M., 1996. Marketable permits, market power, and cheating. Journal of Environmental Economics and Management. 30(2), 161-173.

Woodward, R.T., 2011. Double-dipping in environmental markets. Journal of Environmental Economics and Management. 61, 153-169.

Xepapadeas, A., 1997. Advanced principles in environmental policy. Edward Elgar, pp.170-190

Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Department of Economics
Swedish University of Agricultural Sciences (SLU)
P.O. Box 7013, SE-750 07 Uppsala, Sweden
Ph. +46 18 6710 00, Fax+ 46 18 67 35 02
www.slu.se
www.slu.se/economics

Institutionen för ekonomi
Sveriges lantbruksuniversitet
Box 7013, 750 07 Uppsala
Tel. 018-67 10 00, fax 018 67 35 02
www.slu.se
www.slu.se/ekonomi