THE REVEALED PREFERENCES OF BALTIC SEA GOVERNMENTS: GOALS, POLICY INSTRUMENTS, AND IMPLEMENTATION OF NUTRIENT ABATEMENT MEASURES

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Abstract

Nitrogen and phosphorus loads are considered a major reason for the eutrophication of the Baltic Sea. Until now, most of the abatement has been made at point sources while the implementation of policies for nonpoint sources has not led to equally large reductions in emissions. The purpose of this study is to investigate the determinants of how nutrient abatement measures are implemented by countries in the agricultural sector of the Baltic Sea region. We investigate how goal setting, policy instrument choice, and the level of implementation is determined by characteristics of the abatement measure as well as socio-economic characteristics of the country where it is implemented. Econometric analysis of a cross-sectional data set suggests that income, institutional capacity, and economies of scope in abatement and enforcement are important determinants of policies developed and their implementation.

Keywords: Agri-environmental policy; Baltic Sea; Determinants; Nitrogen; Phosphorus; Policy evaluation.

1. Introduction

Eutrophication of the Baltic Sea has been recognized as a major problem since the 1960s (Boesch et al., 2006; Gustafsson et al., 2012). Excessive nutrient loads are considered a major explanation. Internationally agreed upon nutrient reduction targets for the Baltic Sea were first defined in the Ministerial Declarations of 1988 and 1990. These declarations stipulated that by 1995, emissions of nitrogen and phosphorus to the Baltic Sea should be reduced by 50 percent of the emissions level 1985. These targets were not met, however (Lääne et al., 2002). The Baltic Sea Action Program (BSAP), launched in 2007, defined new load reduction targets (Backer et al., 2010; HELCOM, 2015) and required a decrease in nitrogen and phosphorus loads by 16 and 70 percent, respectively, compared to the reference period of 1997-2003. A subsequent follow-up suggests that substantial progress has been made towards the nitrogen target, where almost ¾ of the intended reduction was achieved, whereas for phosphorus, only ¼ of the targeted reduction was achieved (HELCOM, 2015). Most of the reductions made since the1980s are due to abatement at municipal and industrial point sources, but it has proven to be much more difficult to curb emissions from agriculture, forestry and scattered settlements. Consequently, agriculture remains the main source of nutrient inputs into the Baltic Sea (HELCOM, 2015). It is argued that the failure to reach overall load reduction targets can be explained by inefficient policy instruments and insufficient enforcement (Eckerberg, 1997; European Commission, 2005) as well as rapidly increasing costs of abatement and political difficulties to distribute these costs among countries, sectors, and stakeholders (cf. Gren, Elofsson and Jannke, 1997; Markowska and Zylicz, 1999; Gren, 2001; Elofsson, 2010, 2012; Hyytiäinen and Ahlvik, 2015; Iho et al., 2015). Together, this suggests that the reasons for not meeting targets can be found throughout the whole chain of policy choice, design, and enforcement.

The purpose of this study is to investigate the determinants of how nutrient abatement measures are implemented by countries in the agricultural sector in the Baltic Sea region. We investigate how goal setting, policy instrument choice, and the level of implementation of a measure are determined by characteristics of the abatement measure as well as the socio-economic characteristics of the country where it is implemented. To this end, we use cross-sectional data on 25 different measures in nine countries in the Baltic Sea catchment, compiled by Salomon and Sundberg (2012), in combination with data on institutional and economic conditions in the countries in question. The results suggest that income, institutional capacity, and economies of scope in abatement and enforcement are important determinants of policies developed and their implementation.

There are two strands of economic literature that are relevant for our study: environmental performance and revealed preferences of regulators. The literature on environmental performance is mainly focused on health-related air pollutants and CO_2 emissions while water pollution has received less attention. Most studies use cross-sectional data sets with country-level data. Typically, the dependent variable is either an index of sustainability or environmental performance, which captures multiple aspects of attitudes, policy design, and enforcement (Dasgupta et al., 2001; Grafton and Knowles, 2004); a measure of the state of environmental media, such as air, water, and biodiversity (Grafton and Knowles, 2004); or, the quantity of emissions (Esty and Porter, 2005). Determinants considered include economic factors such as income, competitiveness, and spatial concentration of economic activity (Kaufman et al. 1998; Barrett and Graddy, 2000; Eriksson and Persson, 2003; Esty and Porter, 2005; Farzin and Bond, 2006; Tsurumi and Managi, 2010), as well as institutional factors, such as the level of democracy, multilevel governance, representation in the parliament, consensus culture, social capital, and environmental interest groups (Jahn, 1996; Barrett and Graddy, 2000; Bowles and Gintis, 2002; Neumayer, 2002; Scruggs, 2003; York et al., 2003; Grafton and Knowles, 2004; Wälti, 2004; Farzin and Bond, 2006; Fiorino, 2011). Notably, the role of different factors can vary across pollutants, e.g., the impact of democracy on environmental performance is smaller for water pollutants with a small health impact than it is for air pollutants with a large health impact, which could be due to less activity from health concerned citizens (Barrett and Graddy, 2000; Li and Reuveny, 2006).

The literature on revealed preferences examines the choices of a regulatory agency and, thereby, infers the criteria that determined these choices (McFadden, 1976; Helland, 1998). Most of these studies investigate decisions by a single regulatory agency. For example, Fernandez (2004) examines how project attributes affect the approval of environmental improvement projects by a North American Free Trade Agreement (NAFTA) institution, showing a preference for projects solving trans-boundary wastewater pollution and the "polluter pays" principle. Cropper et al. (1992) demonstrate that EPA decisions on pesticide cancellation are determined by risks, benefits, and interest group activity. Gupta et al. (1996) analyze EPA decisions on the cleanup of contaminated sites, showing the trade-offs between cleanup costs, permanence of remediation, and socioeconomic concerns. Metrick and Weitzman (1996) demonstrate that attributes of endangered species affect listing, spending, and priority decisions in conservation programs. Shepherd et al. (2008) investigate determinants of National Fire Plan (NFP) expenditures on forest restoration and wildfire risk reduction in northern New Mexico (USA), showing that preferences for social equity differ between the programs. Walsh et al. (2015) extend this type of analysis to decisions by multiple local governments, investigating whether geological, political, and socioeconomic factors determine the occurrence of local bans on fracking.

Compared to earlier studies on environmental performance, our study adds to the literature by comparing across both measures and countries and by including several pollutants, which are interdependent in production and in the generation of environmental damage. We also add to the scarce literature on environmental performance and water pollutants and to the literature on revealed preferences by examination of agri-environmental policies aimed at reducing nutrient emissions.

The paper is organized as follows: Section 1.1 briefly describes how eutrophication goals, the associated policy instruments, and enforcement of those policies are determined in the Baltic Sea region. Section 2 presents our hypotheses on the determinants of the resulting goals, policy instruments, and implementation, followed by a description of the econometric approach and the data. Section 3 outlines the results, and Section 4 includes the discussion and conclusions.

2. Policy processes in the Baltic Sea countries

The Baltic Sea catchment includes 14 different countries. Nine of those have a coastline on the Sea: Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden. With the exception of Russia, all are members of the European Union (EU). There are five upstream countries without a coastline: Belarus, Norway, Slovakia, the Czech Republic, and Ukraine. Out of those five, Belarus contributes the most to Baltic Sea nutrient loads (HELCOM, 2015).

2.1. Goal setting

International cooperation on the marine environment are set forth under the Helsinki Convention, which was established in 1974 along with its main body, the Helsinki Commission

(HELCOM). The contracting parties include the littoral countries and the EU. HELCOM compiles pollution source data and provides non-binding recommendations for pollution abatement. Decisions within the framework of HELCOM are taken unanimously. Goals for abatement become binding when adopted by national legislative bodies. These national goals can be set in terms of total nutrient loads to the Baltic Sea, such as implied by the BSAP agreement, as well as in terms of the adoption of specific nutrient abatement technologies or management practices.

2.2. Decisions on regulation

There are both national and international institutions with jurisdiction over environmental protection in the Baltic region. The EU regulates nutrient loads through different directives that are implemented in national legislation, such as the Water Framework Directive, the Marine Strategy Directive, the Urban Waste Water Directive, and the Nitrates Directive. Typically, these directives define minimum emission or recipient standards with which countries need to comply. Countries are free to use more stringent regulation than required in the directives. Specific agri-environmental instruments are included in the EU's Rural Development Program. Countries can choose from a variety of instruments, most of which apply subsidies to environmental measures. National co-funding is required. In addition to the above, countries can choose to regulate emissions on a national or regional basis for sources other than those covered by EU directives and Rural Development Programs.

2.3. Decisions on implementation

The enforcement of policy instruments is usually a shared responsibility of different governments at different levels. There are requirements from the EU with respect to the monitoring and control of measures, which are eligible for support through the Rural Development Programs and with which countries are obliged to comply. Regional or local governments typically carry out the actual control and enforcement of measures in the agricultural sector.

3. Methods

In an ideal world, we would have a well-defined, objective function for society as a whole, and the observed government's behavior could be evaluated on the basis of how well it satisfies society's objectives. However, in practice, policies for eutrophication could serve several purposes. For example, those policies could aim to improve both inland and Baltic Sea water quality and to provide financial support to farmers. This is difficult to account for in the objective function, as we do not know how these different purposes should be traded off against each other. Moreover, the costs and benefits are not well known for many measures. In this section, we therefore instead attempt to identify variables that could influence eutrophication policy given the institutional setting as well as the types of benefits and costs that may arise.

3.1. Determinants of goal setting

The BSAP agreement provides country-wise load reduction targets. For these targets to be met, national policies are necessary that typically include goals, policy instruments, and implementation efforts. National environmental goals are usually determined by politicians, which, and can be of a visionary nature or in terms of quantified performance targets (Edvardsson, 2004).

The setting of a goal does not automatically lead to its implementation. When there are internationally agreed upon goals for load reductions, the incentives for countries to participate, comply, and mitigate depend on their costs and the benefits of doing so and whether the agreement is perceived as fair (Barrett and Stavins, 2003). The BSAP agreement builds, to large extent, on historical emissions, and cost-effectiveness and fairness are not explicitly taken into account (Elofsson, 2010). For some of the countries, several studies suggest that the cost might be high compared to the benefits. This could weaken the incentives for participation, compliance, and mitigation. The easiest way for a country to avoid compliance with an international agreement is to never sign it (Barrett and Stavins, 2003). However, in the case of the Baltic Sea, all major emitting countries have signed the agreement, except Belarus. A country that has signed an agreement could still choose to not comply, either by not setting national operational goals for different abatement measures or by setting goals that are not subsequently followed by the introduction of policy instruments and efforts to implement the instruments.

National policy makers could decide to adopt a goal for a given measure because it is a first step in a process towards compliance. In that case, the country would subsequently introduce a policy instrument and devote efforts to implementation, monitoring, and control. On the other hand, national policy makers could adopt a goal for a measure to make it look as though they comply with the international agreement even if they do not intend to devote efforts to the introduction of policy instruments and implementation. This could be motivated by a wish to have a good relationship with the other countries in other policy areas. Additionally, countries may set goals, but lack the institutional or economic ability to proceed with policy instruments and implementation. We therefore hypothesize that countries choose between **setting a goal for a measure and following up with the introduction of a policy instrument**; **setting a goal, but not following through with the introduction of a policy instrument;** or, **not setting a goal.**

This is affected by income, the institutional capacity of the country, and the characteristics of the abatement measure. **Income** can matter for this choice because higher-income households are likely to be more willing to pay for abatement. **Institutional capacity** can matter because countries with a higher institutional capacity should be more able to come up with a suggestion on an associated policy instrument and to reach a decision on goals and instruments, even if this does not gain all interest groups. Hence, a higher income and higher institutional capacity should both imply a higher likelihood that a measure is associated with both a goal and an instrument. Finally, the characteristics of a measure can matter. As described in the introduction, international agreements for the Baltic Sea have focused equally on **nitrogen** and **phosphorus** reductions for a longer period of time, but more recently the focus shifted to phosphorus. Moreover, phosphorus is the limiting nutrient for inland water bodies, and, hence, the major determinant of eutrophication of lakes and rivers. Therefore, phosphorus could be seen as a "private good" to the countries. In contrast, nitrogen is the limiting nutrient in some parts of the commonly shared sea, and, during certain times of the year, reductions in nitrogen are thus more of a "public good" in nature (HELCOM, 2009). A country might choose to set a goal for a measure that reduces nitrogen, but which is not accompanied by a policy instrument, to make it look like the country complies with international agreements. Additionally, a country could choose to set no goal for a measure that reduces nitrogen because it has the opportunity to free-ride on reductions made by other countries. We, therefore, expect to find more nitrogen measures with a goal and no instrument or without a goal.

3.2. Determinants of policy instrument choice

The next step in the policy process is a decision to introduce a policy instrument that regulates the measure. The introduction of a policy instrument is associated with costs to the national government for design and negotiation with different political parties and interest groups (McCann et al., 2005). Depending on the chosen instrument, it will also give rise to costs or revenues to farmers. The most common agri-environmental policy instruments in the EU are command-and-control and subsidies, while taxes are seldom applied (Salomon and Sundberg, 2012). Subsidies to abatement activities have a positive effect on farmer income, while regulations without an accompanying subsidy imply a cost. Subsidies generate a cost to the government, while regulations can generate costs through their effect on farmers' production costs and, hence, competitiveness (Goulder and Parry, 2008). Economic instruments such as taxes and subsidies are typically favored by economists, as targets can be met at a lower cost to society as a whole. At the same time, regulations can be favored by politicians who are concerned about fairness across income groups and for the higher political feasibility (Goulder and Parry, 2008).

We hypothesize that the decision on policy instruments can be expressed as one of whether to apply **command-and-control regulations**, **subsidies**, **both regulation and subsidies**, or **none of those**; furthermore, we hypothesize that this decision is affected by income, institutional capacity, and measure characteristics. A higher **income** on a national level could increase the use of subsidies given the need for national co-funding of measures included in the Rural Development Programs, thus increasing the probability of measures being subsidized. Given the existence of considerable water quality problems in the sea and in the inland surface waters, a higher **institutional capacity** should increase the likelihood that some policy instrument is introduced compared to countries with lower institutional capacity. If one of the two nutrients is seen by national policy makers as a larger problem, that particular nutrient should be more likely the subject of some policy instrument. Hence, if **nitrogen** measures are more frequently subject to some policy instrument compared to **phosphorus**, this could indicate a relatively larger concern for the environmental status of the Baltic Sea as compared to the concern for national inland water quality. Furthermore, we hypothesize that policy instruments simultaneously targeting nitrogen and phosphorus should more frequently appear because policy makers can be assumed to have a preference for **economies of scope** in abatement. Finally, we hypothesize that it matters whether the measure requires costly **investment** or only additional **labor time** from the farmer. A change to a new technology typically requires an investment. Due to the considerable cost in the short term, it is therefore unlikely that the measure is implemented unless associated with a subsidy. In contrast, measures that only require a change in management imply additional labor and might be subsidized to a lesser extent as the opportunity cost of farmers' working time is less obvious to politicians. Hence, measures that employ a new technology can have a higher probability of being subsidized. Finally, we assume that the **number of measures implemented** in a country can affect the degree of implementation. On one hand, if there is a large number of measures implemented, the level of implementation of the individual measures could be lower and reach the same effect in terms of reductions. On the other hand, there could be economies of scope and scale in implementation, for example, if several measures could be monitored simultaneously, or if the administrative framework is similar for enforcement of different measures. As countries have not reached targeted reductions, we are inclined to believe that the latter effect dominates.

3.3. Determinants of achieved implementation

There is very scarce literature on achieved levels of implementation of nutrient abatement in the Baltic Sea region. This includes some official estimates of countries' reductions in coastal loads (Lääne et al., 2002; HELCOM, 2015), a survey of the use of policy instruments in the agricultural sector (Andersen et al., 2014), and an evaluation of the cost-effectiveness of Swedish nutrient abatement policies (Elofsson, 2012). The limited availability of data on implementation levels may explain there are even fewer studies investigating the determinants of implementation. An exception is Auer and Nilenders (2001), who evaluate the so-called Baltic Sea Joint Comprehensive Environmental Action Program, which was launched in the 1990s by the countries surrounding the Baltic Sea. In this program, 132 ‘hot spot’ point sources were identified and designated for cleanup and/or restoration, and Auer and Nilenders (2001) argue that financial constraints, temporary economic recessions, and institutional capacity affected implementation. For agricultural measures, Eckerberg (1997) shows that implementation is weak at the local level, which is argued to be driven by a concern for the costs to local agents.

We hypothesize that implementation is determined by the resources available in society, institutional capacity, the choice of policy instrument, and the characteristics of the abatement measure. If the **income** is higher, more resource can be devoted to monitoring and enforcing policies. A higher **institutional capacity** implies that the organization of monitoring and enforcement could work better. In both cases, a higher level of enforcement can be expected. Monitoring and enforcement is typically carried out at the regional or local scale; civil servants at this level could be more concerned with pollutants with a higher local impact, inferring that they could favor addressing **phosphorus** pollution compared to **nitrogen** pollution. We thus expected higher implementation for phosphorus measures. In addition, it could matter whether measures are easy to monitor and, hence, to sanction. Measures that require a certain **technology** are easier to monitor than measures that only require additional labor time, i.e., **management measures**. Hence, implementation costs may be higher for the former. Finally, we hypothesize that **legislation** will induce a higher level of implementation, as legislative measures are binding for all farmers, while voluntary **subsidy** schemes are only adopted by those who will gain from doing so.

3.4. The econometric approach

The decision on goal is estimated using a logistic regression model:

$$logit[P(Y_{ij} = 1)] = k + \beta_1 ln(I_j) + \beta_2 C_j + \beta_3 N_i + \beta_4 T_i, \quad (1)$$

where Y_{ij} denotes the structure of the goal for measure *i* in country *j* and can belong to one of two categories: (1) there is a goal which is followed by the introduction of a policy instrument, and (2) there is a goal, but it is not followed by the introduction of a policy instrument, or there is no goal[1]. The variable I_j is a measure of income in society in country *j*. This variable was log-transformed to make it more symmetric in order to distinguish better between countries with similar low values (the majority) at the same time as the few countries with high values have a little less influence on the model. C_j is a measure of institutional capacity in society in country *j*, N_i indicates whether the measure reduces nitrogen or phosphorus or both, and T_i indicates whether the measure is one that requires a change of technology, or requires a change in management practice, or both. Finally, *k* is an intercept of the estimated equation.

In a similar manner, the choice of policy instrument is modeled using a multinomial logistic regression model with four levels in the response variable:

$$ln\left(\frac{P(Z_{ij}=1)}{P(Z_{ij}=4)}\right) = k + \beta_1 ln(I_j) + \beta_2 C_j + \beta_3 N_i + \beta_4 T_i, \quad (2)$$

[1] The reason for including the case with no goals in the latter category, instead of having a separate category, is empirical: there are only five observations in our data set with no goal. We find that this category division makes sense by dividing the measures into a group where goals that are “effective” are included in the first category, and those that are not in the latter.

and similarly for $P(Z_{ij} = 2)$ and $P(Z_{ij} = 3)$, with $Z_{ij} = 4$ as reference level in all cases. Here, Z_{ij} is the choice of policy instrument for abatement measure *i* in country *j*, where the choice of instrument can be one of the four alternatives: (1) legislation, (2) subsidy, (3) legislation and subsidy, or (4) no policy instrument. Explanatory variables are chosen as above.

Finally, the level of implementation is estimated using a linear regression model:

$$E_{ij} = k + \beta_1 ln(I_j) + \beta_2 C_j + \beta_3 N_i + \beta_4 T_i + \beta_5 A_j + \beta_6 M_1 + \beta_7 M_2 + \beta_8 M_3 + e_{ij}$$

where E_{ij} is the relative level of implementation measured on a scale from 0 to 10 in relation to the goal, of measure *i* in country *j*, and A_j is the number of measures implemented in country *j*. Variables M_1 to M_3 are indicator variables that take the value 1 if the corresponding policy instrument is used, e.g., $M_1 = 1$ if legislation is used. As above the four alternatives are (1) legislation, (2) subsidy, (3) legislation and subsidy, or (4) no policy instrument. The last alternative is again set as reference level. Other explanatory variables included are defined above. The error term e_{ij} is assumed to be independent and normally distributed with equal variances.

3.5. Data

For the empirical analysis, we use a survey by Salomon and Sundberg (2012) on the implementation of agricultural measures to reduce nitrogen and phosphorus leakage in ten countries in the Baltic Sea drainage basin[2]. The survey was conducted within the framework of the EU-financed research project Baltic Compass, where 25 agricultural measures were identified that can be employed to reduce nitrogen and phosphorus leakage. Most of the measures are subject to country-specific regulation in at least some of the countries, and some are eligible for economic subsidies. Survey data describe the situation in September 2011, except for Russia, where data apply to the situation in the Leningrad Oblast region in the end of 2012. In addition, we use national statistical data obtained from the World Bank. A description of all measures, and information on their characteristics, can be found in the Appendix. Remaining data used for the analysis can be found in the Supplementary Material.

3.6. Data on goals, policy instruments, and implementation level

Salomon and Sundberg (2012) report on whether countries have adopted goals for the different measures or not, but do not compare the level of the goals. They explain that it is not possible directly compare goals in quantitative terms because the formulation of goals as well as their quantification differs across countries. For example, most countries have goals for the amount of vegetative cover in autumn and winter on arable land. However, the definition of what is an approved winter crop differs between countries, and only four of the countries have goals for catch crops. Also, a majority of the countries have legislation for manure storage, but there is no information on the number of farms affected by the regulations. Adding to Salomon and

[2] Belarus, Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia, and Sweden.

Sundberg's (2012) arguments against the comparability of goals in quantitative terms, one can therefore note that it is not possible to say whether the goals for a given measure are ambitious or not in the different countries, i.e., have a considerable environmental and/or economic impact, because the maximum technical and economic potential of the measure is not well known in quantitative terms. Thus, there is currently not sufficient information for a comparison of goals in quantitative terms.

Following the approach Salomon and Sundberg (2012), we therefore treat goal adoption as a binary variable, where 1 indicates that the country has a goal for the measure in question and 0 that it does not. The survey includes information on regulation and subsidies for each measure. We use data on whether the measures are regulated or not and on whether they are subsidized or not, thereby obtaining four possible combinations of policy instruments as indicated above in Section 3.4. The level of implementation of a measure is defined as the degree of achievement of the national goal and measured on a scale from 0 to 10, where 0 indicates that the measure is not implemented at all, and 10 that the goal has already been reached.[3]

3.7. Measure characteristics

Salomon and Sundberg (2012) provide information on whether the measures affect nitrogen, phosphorus, or both. We treat this as three different categories. It also includes information on whether the measure requires a change in management, a change in technology, or both. This variable is then also divided into three categories.

3.8 Income and institutional capacity

[3] The reported level of implementation is based either on quantitative information on goals and implementation levels or, in some cases, on expert judgment.

As a proxy for the willingness to pay for environmental improvements, we use the average purchase power adjusted GDP per capita from 2000 to 2010 (EUR in 2010 value) obtained from the World Bank. The motive for using data prior to 2011 is that policy processes take time and that willingness to pay during that process is likely to determine the outcome. Furthermore, the World Bank provides Governance Indicators that reflect institutional capacity. These indicators include, e.g., control of corruption, government effectiveness, regulatory quality, and voice and accountability. We have calculated the average of the values between 2000 and 2010. The four indices are highly correlated for the ten countries in our dataset, and we therefore chose to use only the index for regulatory quality, RQ, which seems to be the most relevant for our study as the index should reflect the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.

4. Results

In the following, we present results from the analysis of goal setting, policy instrument choice, and implementation.

4.1 Goals

Using the logistic regression in Equation (1), we model the probability of having a goal set and followed by the introduction of a policy instrument, compared to having a goal but not no policy instrument or having no goal. The results show that the probability of setting a goal followed by the introduction of a policy instrument is significantly influenced by the GDP per capita and whether the measure affects nitrogen or phosphorus. The highest probability to set a goal while also having a policy instrument in place is found for measures that reduce both nitrogen and phosphorus, followed by measures that only reduce nitrogen. Measures that reduce both nutrients have five times higher odds of having a goal and policy instrument set compared to measures that only reduce phosphorus, see Table 1. Countries with a higher GDP per capita have higher odds to set goals than countries with a lower GDP per capita: a 1% increase in GDP per capita leads to an approximate 3.7 times increase in the odds. The uncertainty in these estimates are however quite large as seen from the confidence limits.

Table 1

Estimated odds ratios and confidence limits for the variables included in the logistic regression. Dependent variable is goal, Y_{ij}. Numbers in bold indicate statistically significant results at a 5% level.

Variable		**Odds Ratio**	**95% Confidence Limits**	
			Lower	**Upper**
Logarithm of GDP per capita, $ln(I_j)$	1% increase	**3.674**	1.285	10.507
RQ, C_j	1 unit increase	0.868	0.603	1.249
Nitrogen/ Phosphorus, N_i	Both compared to phosphorus only	**5.172**	1.929	13.864
	Nitrogen only compared to phosphorus only	2.570	0.881	7.497
Management/ Technology, T_i	Both compared to technology only	0.644	0.339	1.224
	Management only compared to technology only	0.513	0.195	1.348
Number of observations		240		
Likelihood ratio		29.3		
P-value (χ^2)		< 0.001		
Percentage of correct predictions		69.6%		
Pseudo R^2 [a]		11.69%		

[a] Tjur (2009)

4.2 Policy instruments

It is not necessary for a goal to be in place for a specific measure in order for a policy instrument to be introduced. Several of the countries apply subsidies (5 countries) or legislation (8 countries) or both (4 countries) for measures that have no goal set, see Table 2. All countries that have goals set use subsidies at least for some of the measures.

Table 2

Number of measures in different combinations of policy instrument use and whether a goal is set or not. In parenthesis, the number of countries that use this combination at least once.

	Legislation	Subsidy	Legislation and subsidy	No policy instrument
No goal set	28 (8)	12 (5)	6 (4)	65 (8)
Goal set	22 (5)	45 (10)	20 (7)	7 (3)

In a multinomial regression analysis, the choice of policy instrument is modeled using the logarithm of GDP per capita, RQ, whether the measure affects nitrogen and/or phosphorus, and whether the measure requires technological advances, changed management practices, or both. Among those, RQ and the nitrogen/phosphorus efficiency showed significant effects. A higher value for RQ leads to a higher odds to adopt legislation, either with (odds ratio: 3) or without subsidy (odds ratio: 2.2) compared to not using any policy instrument. The odds of adopting subsidies, with or without legislation, increase if the measure is both nitrogen and phosphorus efficient (odds ratios 3.4 and 27, respectively, but including high uncertainty in the latter case). The overall model is highly significant with a p-value of < 0.001 for the Chi-square test (Likelihood ratio statistics =65.8). 47% of all cases were predicted correctly by the model.

4.3 Implementation

A multiple regression model was used to model the level of implementation. For this analysis, measures that were not implemented in any of the countries were removed. The number of implementations per country and the policy instrument used were the most influencing factors, see Table 3. The number of implementations has a significant positive effect on the mean level of implementation for the individual measures. The use of subsidies alone, or in combination with legislation, increases the level of implementation significantly compared to not using a policy instrument. Additionally, the use of legislation alone has a positive effect on implementation level, but to a smaller extent.

Table 3

Results from OLS regression with level of implementation, E_{ij}, as dependent variable.

Variable		Parameter estimates	P-value
(Intercept)		-13.36	0.16
Logarithm of GDP per capita, I_j		0.839	0.40
RQ, C_j		0.5	0.13
Nitrogen/ Phosphorus, N_i	Both compared to phosphorus only	1.38	0.23
	Nitrogen only compared to phosphorus only	1.11	0.34
Management/ Technology, T_i	Both compared to technology only	0.57	0.13
	Management only compared to technology only	0.36	0.47
Policy instrument, $M_1 - M_3$	Only legislation compared to none	**1.62**	0.036
	Only subsidy compared to none	**4.42**	<0.0001
	Legislation and subsidy compared to none	**3.55**	<0.0001
Number of implementations, A_j		**0.45**	<0.0001

Number of observation	**226**
F-test	**16.52**
P-value	**< 0.001**
R^2	**43.5%**

5. Discussion and conclusions

The aim of our study was to investigate the determinants of goal setting, policy instrument choice, and the level of implementation for nutrient abatement measures in the agricultural sector of countries in the Baltic Sea region. We use a cross-sectional data set of 25 measures in ten countries for the analysis. Logistic, multinomial logistic; and ordinary least squares models are used for the analysis of goal setting, policy instrument choice, and the level of implementation, respectively. The results show that income significantly affects the choice of setting a goal, confirming results from earlier studies on countries' environmental performance. This could indicate a tendency towards a more fair distribution of the abatement burden, as comparatively higher efforts from high-income countries can be motivated from an equity perspective (Gren, 2008; Hautakangas et al., 2014). However, we find no significant effect of income on implementation, and hence there is no indication of equity with respect to actual abatement efforts.

The results further suggest that countries are more inclined to set goals and pay subsidies for measures that reduce both nitrogen and phosphorus. Policy makers who make decisions with a limited amount of information on the costs and benefits of the different measures might interpret synergies in abatement as an indicator of cost-efficiency (cf., e.g., Scheuer, 2006). Several earlier studies on Baltic Sea policies have concluded that measures that affect both nitrogen and phosphorus are an important part of a cost-effective abatement policy (Gren et al., 1997;

Elofsson, 2003; Elofsson, 2010; Hyytiäinen and Ahlvik, 2015). However, it cannot be guaranteed that cost-efficiency results from the measures that provide such synergies in abatement in the studied dataset. For example, this will not be the case if measures that reduce both nutrients are a lot more expensive than other measures. Additional information on the costs and effects of the measures included in the dataset would be necessary to ascertain that the higher implementation of measures that reduce both nutrients leads to reduced costs for meeting Baltic Sea nutrient targets.

Further, results indicate the presence of synergies in monitoring and enforcement. This could be due to cost savings under coordinated monitoring, data collection, and analysis. There is also a policy lesson to be drawn from such a result -- if there are synergies in monitoring and enforcement, further concentration of measures in countries or regions can be motivated if this permits better coordination of such activities. Finally, our results indicate a higher level of implementation for measures that are subsidized, with or without simultaneous regulation. This may seem counterintuitive, as intuition tells you that regulation is a more stringent measure. Possible explanations for this outcome are that regulations are weakened when implemented at the local level (Eckerberg, 1997), whereas this might not occur to the same extent in the presence of economic incentives. Additionally, resources devoted to monitoring and enforcing might be larger for measures that are subsidized given the requirements from the EU for measures included in the Rural Development Programs. In addition, the result should be interpreted in the light of the fact that the implementation variable expresses the degree of implementation in relation to the target, rather than the absolute level of implementation. Thus, it is possible that the higher degree of implementation for subsidized measures reflects a situation where targets are set lower for such measures. It is not possible to infer from data whether this is the case or not.

The present study has limitations that should be recognized when interpreting the results. Among those, the use of a cross-sectional data set implies that we are not able to account for the time dimension of policy development. There is no information in the data on the timing of decisions on goals and policy instruments. Additionally, due to the comparatively small size of the data set, we can only account for a limited number of explanatory variables, thus including only a single governance index, and ignoring the fact that the phosphorus effect of some measures is uncertain, see Salomon and Sundberg (2012). In addition, we have not accounted for the possibility of spatial spillovers, which can be present in environmental policy decisions, see e.g., Fredriksson and Millimet (2002). Spatial spillovers in policy implementation, implying that countries follow or compensate for decisions taken by their neighbors, could be an interesting topic for future research on the studied issue.

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APPENDIX

Description of abatement measures included in the analysis

The below description of the abatement measures follows Salomon and Sundberg (2012), where further details can be found.

1. **Promoting long-term grass cultivation on arable land.**

Cultivation of permanent grass or legume/grass crops on arable land can reduce nitrogen and phosphorus leaching and surface run-off losses, as well as soil erosion, compared with annual crops on arable land.

2. **Vegetative cover in autumn and winter on arable land**

Annual winter crops take up available nitrogen and phosphorus from the soil more efficiently than annual spring crops under conditions with high precipitation and low temperature. Catch crops can be under-sown in the main crop simultaneously or just after sowing of the main crop. When the main crop is harvested, the catch crop has an established root system ready to take up nitrogen from the soil during late summer and autumn, thereby reducing nitrogen leaching.

3. *Soil tillage management*

3.1 Reducing soil tillage

Reducing soil tillage by conversion from ploughing to a minimal or no tillage system, or conversion from deep ploughing to shallow ploughing can reduce mineralisation of organic matter in soil.

3.2 Time of the year effects

Postponed tillage, from autumn to spring, means that the mineralised nitrogen becomes available for uptake by the established spring crop, which also provides surface cover.

4. Fertilization management

4.1 Adapting the amounts of chemical and organic fertilizers applied

Fertilizer amounts can be adapted by controlling animal density and by setting up fertilization plans. Sampling and analysis of nutrients in manure and arable soil provides information of the appropriate amounts of fertilization.

4.2 Calculating nutrient balances on farm and/or field level

Calculating nitrogen and phosphorus inputs/outputs and balances on farm and/or field level is a both performance tool and a policy tool for assessing the environmental impact.

4.3 Avoiding the spreading of chemical fertilizers and manure during high-risk periods

The timing of chemical fertilizer and manure application is a key factor in achieving high plant nutrient use efficiency and to avoid large nitrogen leaching loads.

4.4 No or reduced phosphorus fertilizer for high soil phosphorus fields or part of fields

Phosphorus leaching has large spatial and temporal variations and can be influenced by several interacting factors. Consideration of site-specific factors is important in order to identify needs for measures to reduce phosphorus leaching.

5. Improved spreading technology for manure and chemical fertilizers

5.1 Site-specific dosage

The use of a GPS in combination with steering aid systems means that the fertilizer can be spread with a minimum of bare spots and overlaps. Also, with a GPS it is possible to map field properties and use this information for site-specific spreading of fertilizers.

5.2 Combi-drilling

Combi-drilling involves placing seed and fertilizer in the soil using a single machine in one work operation. Thereby, nitrogen dosage for a particular yield level can be reduced.

5.3 Incorporation

Incorporation of manure and chemical fertilizers can be achieved with equipment such as disc or tine cultivators. It is usually performed in a separate work operation. This reduces ammonia losses, surface runoff and drain-flow losses.

5.4 Liquid manure

The distribution of liquid manure with respect to crop needs can be significantly improved with band spreading, the use of control systems that adjusts spreading to driving speed, and injection, where liquid manure is applied directly into the active layer of soil.

5.5 Solid manure

Disintegration equipment can break up the manure better and gives greater working width and more uniform spreading laterally.

5.6 Manure spreading and ammonia emissions – general measures

Joint consideration of variables affecting ammonia emissions from manure after spreading, such as soil water content, air temperature, wind speed, manure type, dry matter content of manure, total ammoniacal nitrogen content of manure, application method and rate and manure incorporation, can significantly reduce ammonia losses.

6. Avoiding the application of chemical fertilizers and manure to high-risk areas

Examples of high risk areas on arable land are those with a significant slope, with flushes draining to a nearby watercourse, soils with cracks over field drains, fields adjacent to water or fields with phosphorus values beyond the agronomic optimum range.

7. Measures to optimize soil pH and improve soil structure

Measures to improve soil fertility, structure and pH, such as liming, can increase crop plant nutrient use efficiency and decrease the risk of nitrogen and phosphorus leaching and surface run-off.

8. Adapted feeding

8.1 Adopting phase feeding of livestock

Livestock at different growth stages and stages of the reproductive cycle have different optimum nutritional requirements. Individually adapted feeding reduces excretion of nitrogen and phosphorus.

8.2 Reducing dietary nitrogen and phosphorus intake

Farm animals are often fed diets with higher than recommended contents of nitrogen and phosphorus as a safeguard against loss of production. Balancing of nutrients in feed reduces environmental impacts. This requires careful analysis of nutrient content and dietary value.

8.3 Phytase supplementation

Supplementation of synthetic phytase to pig feed reduces the need for addition of mineral phosphate. Phytase increases the availability of phosphorus, implying that the phosphorus content of feed can be reduced.

8.4 Wet feed and fermentation

Endogenous phytase in grain can be activated by wetting pig feed before feeding, thereby reducing the need for mineral phosphorus supplementation. Therefore, wet feed systems can utilize feed with a lower phosphorus content. Fermentation of the feed can also reduce the need for mineral phosphate supplementation, and occurs naturally in wet feed after a certain amount of time, albeit the method is still under development.

9. Reducing ammonia losses in animal houses

Ammonia emissions from animal houses can be reduced through increased nitrogen use efficiency, decreased areas with manure in the house, avoiding high temperature in the house and in manure, adapting air flows along manure surfaces, and use and choice of bedding material.

10. Storage of manure

Adequate collection and storage facilities provide the possibility to choose a time to apply manure to fields when the crops can utilize nitrogen and phosphorus, thereby reducing leaching. Manure storage must be of such a quality that it prevents nitrogen, phosphorus and manure losses.

11. Constructed wetlands for nutrient reduction/retention

11.1 Sedimentation ponds

Small surface flow wetlands designed primarily to retain phosphorus, and are suitable in highly intensive small-scale agricultural areas. The accumulated sediments in the basin need to be removed on a regular basis for maintenance.

11.2 Constructed wetlands

Large free water surface wetlands designed and constructed primarily for removal nitrogen, phosphorus, and other pollutants from run-off water through sedimentation, biological and chemical transformation and degradation and plant uptake. Constructed wetlands can have additional benefits in terms of improved biodiversity, water storage capacity, resource recovery, irrigation possibilities and production of crop biomass.

12. Buffer zones along water areas and erosion-sensitive field areas

Buffer zones are uncultivated areas between arable fields and water courses, main ditches, ponds, lakes or gulfs. Buffer zones are particularly useful in erosion-sensitive field areas. They reduce the speed of water surface run-off, hence mitigating losses of eroded aggregates, soil particles and particulate phosphorus and other soil-borne pollutants, and provide conditions for biological and chemical transformation of pollution.

Table A1

N and P indicate impact on nitrogen and phosphorus, respectively. M and T indicate that the measure is a management or technology measure, respectively

	N	P	M	T
1. Promoting long-term grass cultivation on arable land	X	X	X	
2. Vegetative cover in autumn and winter on arable land	X	X	X	
3. Soil tillage management				
3.1. Reducing soil tillage	X	X	X	X
3.2 Time of the year effects	X	X	X	
4. Fertilization management				
4.1. Adapting the amounts of chemical fertilizer and manure applied	X	X	X	X
4.2. Calculating nutrient balances on farm and/or field level	X	X	X	
4.3. Avoiding the spreading of chemical fertilizers and manure during high-risk periods	X	X	X	
4.4. No or reduced phosphorus fertilizer for high soil phosphorus fields or part of fields		X	X	X
5. Improved spreading technology for manure and chemical fertilizers				
5.1 Site-specific dosage	X			X
5.2 Combi-drilling	X			X
5.3 Incorporation	X			X
5.4 Liquid manure	X			X
5.5 Solid manure	X			X
5.6 Manure spreading and ammonia emissions – general measures	X		X	X
6. Avoiding the application of chemical fertilizers and manure to high-risk areas				
7. Measures to optimize soil pH and improve soil structure	X	X	X	
8. Adapted feeding				
8.1 Adopting phase feeding of livestock	X	X	X	X
8.2 Reducing dietary nitrogen and phosphorus intake	X	X	X	
8.3 Phytase supplementation		X	X	
8.4 Wet feed and fermentation		X	X	X
9. Reducing ammonia losses in animal houses	X		X	X
10. Storage of manure	X	X	X	X
11. Constructed wetlands for nutrient reduction/retention				
11.1 Sedimentation ponds		X	X	X
11.2 Constructed wetlands	X	X	X	X
12. Buffer zones along water areas and erosion-sensitive field areas	X	X	X	

Source: Salomon and Sundberg (2012).