Norwegian University of Life Sciences
Faculty of Social Sciences
School of Economics and Business

Master Thesis 2015
30 credits

When Permits Don't Matter

A study of Norwegian firms' level of compliance with pollution permits

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Acknowledgement

This thesis is the concluding piece to our graduate studies at the Norwegian University of Life Sciences. We would like to begin by thanking our supervisor, Ståle Navrud at NMBU, for showing a genuine interest in our work. We appreciate his contributions and guidance throughout this process.

We are also very grateful for the help we have received from Ragnhild Orvik and Øyvind Hetland at the Norwegian Environment Agency. Further, we owe Marit Klemetsen at Statistics Norway our gratitude for help in gathering and compiling data used in our analysis.

We appreciate the companionship with our fellow students at NMBU, as well as all help and support from family and friends during the writing process.

We take full responsibility for all potential errors and faults in this thesis.

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15.05.2015

Abstract

In Norway, we assume that the government implement and enforce policies in an efficient manner. Yet, previous research suggests that a majority of Norwegian firms have been violating environmental regulations.

The main objective of this thesis is to explore the regulatory and firm-specific factors that attribute to Norwegian firms' level of compliance to non-tradable pollution permits over time. The plant-specific panel data is obtained from the Norwegian Environment Agency and includes monitoring results from oil and gas and land-based industry in the period between 1997 and 2011. A logistic regression is applied to examine the level of compliance, consecutive violations and the severity of violations in question.

We identify significant effects on compliance from both firm characteristics and monitoring methods used. We find that more thorough monitoring is an important factor to fuel greater compliance among Norwegian firms, with the potential to reduce the issue of asymmetric information and incentivize firm transparency. Additionally, we find that an increase in the total expected penalty may increase firms' focus on precautionary measures, resulting in a reduced number of violations. Lastly, we do not find evidence that the level of compliance is higher than explained by rational crime theory, hereby renouncing the validity of the "Harrington paradox" among Norwegian firms with pollution permits.

Sammendrag

I Norge antar vi at myndighetene implementerer og håndhever lover og regler på en god og effektiv måte. Likevel viser tidligere forskning at de fleste norske bedrifter bryter miljøreguleringer.

Formålet med denne oppgaven er å undersøke enkelte regulatoriske forhold og bedriftsspesifikke faktorer, og i hvilken grad de påvirker overholdelsen av norske miljøreguleringer over tid. Anleggsspesifikke data er samlet fra Miljødirektoratet, og inkluderer kontrollresultater i perioden mellom 1997 og 2011. En logistisk regresjon er benyttet for å analysere nivået av overholdelse, sammenhengende eller etterfølgende avvik og alvorlighetsgraden av de aktuelle avvikene.

Vi har identifisert signifikante effekter av både bedriftspesifikke faktorer og tilsynsmetoder på overholdelse av utslippstillatelser.

Vi finner at grundigere tilsyn er en av de viktigste faktorene som bidrar til høyere grad av overholdelse av utslippstillatelser blant norske firmaer i henholdsvis olje og gass og land-basert industri. Grundigere tilsyn og gjennomgripende kontroller vil på sikt gi incentiver for åpenhet, da det vil bli vanskeligere å skjule lovbrudd.

Videre finner vi at en økning i den totale forventede straffen potensielt kan øke bedriftens fokus på forebyggende tiltak, noe som igjen kan føre til en reduksjon i antall avvik. Vi finner ikke bevis for at nivået for overholdelse er høyere enn forklart av teorien for rasjonell kriminell atferd. Vi finner derfor ikke grunnlag for at "Harringtonparadokset" finnes blant norske bedrifter med utslippstillatelser.

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1. INTRODUCTION

The Norwegian government is planning what they call an "environmentally friendly restructuring" and municipalities are increasingly encouraging green behaviour by campaigning environmental awareness. While individuals are induced to minimize consumption, recycle household waste and bike to work, previous research reveals that a majority of Norwegian firms are violating environmental regulations (Ministry of Climate & Environment, 2014a; Nyborg & Telle, 2006).

The alarming state of our global environment has led to an increased attentiveness to the climate debate. In Norway, increased media coverage on environmental issues has led to greater attention to the topic. There is a growing realization that we live in a world of imprudent material use, uncontrolled consumerism and fossil fuel dependency. As a result, individuals are faced with an increasing pressure to consider the environment in their every-day decisions. The same token should be expected of firms. It seems like a paradox that individual members of society are facing a greater social pressure to pollute less, when the environmental threat presented by firms is much larger.

The OECD considers Norway one of the pioneers in international climate negotiations, and Norwegian public policy on environmental degradation to be among the world's most ambitious (OECD, 2011). Environmental policy in Norway is coherent with the notion that norwegian firms face quite strict regulations such as green taxes, pollution fees, technology requirements and pollution permits. With thorough regulations, one should also assume that firms feel a pressure to abide. The relevant predicament here, in terms of social welfare theory, is the relationship between profit oriented firms and ecological sustainability. Within the literature, this has been a hot topic. Several authors claim that the contradictions between environmental conservation and profit can be a false dichotomy, and that firms are increasingly acknowledging the potential benefits of reducing environmental impacts (Porter & Van der Linde, 1995).

Several studies have investigated firms' compliance with environmental regulations, specifically in the US, and claim that firms comply at a higher rate than assumed. Heyes and Rickman (1999) denoted this as the "Harrington paradox". In Norway, on the contrary, previous research indicate that the majority of Norwegian firms that have been granted non-tradable pollution permits have, in the past, been violating plant-specific demands, and consequently, the law (Walle, 2003; Nyborg & Telle, 2006). This leads us to believe that the regulatory framework in itself is perhaps stringent enough, but that the enforcement of the requirements may not be sufficiently effective.

Norwegian research on the topic has used panel data from the Norwegian Environment Agency (NEA) to investigate compliance to pollution permits. Most of these papers have solely presented the data and used descriptive statistics to analyze the compliance in the regulatory environment in Norway (Walle, 2003; Telle & Nyborg, 2006). Several international studies have investigated similar cases of monitoring, enforcement and compliance to other "command and control" instruments through logistic regressions (Cohen, 1987; Winter & May, 2001; Stafford, 2002). We have, to the extent of our knowledge, failed to find similar studies on Norwegian firms' compliance with non-tradable permits. Therefore, we are interested in investigating those factors that affect compliance through a logistic regression.

1.1. Problem statement and hypotheses

The objective of this thesis is to analyze Norwegian panel data on monitoring and enforcement to evaluate firms' compliance to pollution permits. The intent is to look at what characterizes those firms who violate government-issued permits, and to establish if there is a recurring trend of non-compliance. By examining all controls in the offshore and land-based industry that were performed by NEA in the period of 1997 to 2011, we will attempt to investigate the following research question:

What are the factors that attribute to Norwegian firms' level of compliance with pollution permits? Does the impact differ by:

i. **Firm characteristics**
ii. **Monitoring methods**
iii. **The period in which the control was performed**

From economic theory we tend to look at the individual, moreover the firm, in a relatively uncomplicated manner. As a general rule we assume that self-regarding agents have the capability of making sensible choices with the intention of maximizing their own utility. Based on this notion, one can further assume that when a firm is facing an environmental regulation, there are some considerations that will account for the decision they will make. General assumptions about rational behavior would lead us to think that firms comply with regulations based on fear of being caught violating them, and consequently the punishment that follows, or because of some moral responsibility to comply.

i. Firm characteristics

As the decision to comply depends on a firm's level of risk-aversion, and the magnitude of damage to the firm's reputation and potential economic penalty if one is caught in violation, emphasis is given to firm characteristics, more specifically to the type of industry and risk class the firm belongs to. First, we will focus on the type of industry, where we have specifically looked at controls performed in oil and gas versus land-based industry. Firms in the oil and gas sector have notoriously been labeled as "bad guys" in terms of environmental performance, especially with regards to not carrying their share of responsibility in preserving natural resources (TNS Gallup, 2014). The public opinion may rest on the nature of the oil and gas industry per se; firms in this sector are generally perceived to have poor environmental performance because they are operating within a field that solely relies on non-renewable energy sources. Based on this notion, we postulate the three following hypotheses:

H1a: *Oil and gas less compliant*

Firms in land-based industry are more likely to comply with the pollution permits than firms in the oil and gas sector.

H1b: *More consecutive violations in oil and gas*

Firms in the oil and gas sector are more likely to have offenses in two or more successive controls than firms in land-based industry.

H1c: *More severe breaches in oil and gas*

When caught in non-compliance, firms in the oil and gas industry are more likely to have severe violations than firms in land-based industry.

Further, we use NEA's assigned risk classes as a measure to examine if the expected pollution threat of firms influence the level of compliance. The measure will also be used to explore the likelihood of consecutive violations, and assess the severity of the deviations. This will not say anything about the firm's level of risk-aversion per se, however, the assigned risk class gives us some insight into the level of penalties the firm will be faced with, which increases the expected penalty. NEA's firm-level risk classification will be explored in the following three hypotheses:

***H2a**: Less compliance in risk class 1*

Firms that represent the highest potential damage to the environment, designated by risk class 1, have a higher tendency towards violating the demands specified by the pollution permits than firms in lower risk classes.

***H2b**: Less repeated offenders in low-risk firms*

Firms that represent the lowest potential damage to the environment, designated by risk class 3 and 4, are less likely to have violations in consecutive controls than firms in risk class 1.

***H2c:** Less severe deviations among low-risk firms*

Firms assumed to represent the lowest pollution threat, designated by risk class 3 and 4, are less likely to have severe deviations than firms in risk class 1.

ii. NEA's monitoring methods

The level and persistency of compliance might not solely be a factor of firm characteristics, but can have some relation to the type of monitoring method used by NEA. Here, we will investigate the control type and number of items controlled during an inspection. Moreover, since the NEA categorizes firms in their monitoring schedule based on previous performance, we will investigate if controls reveal more violations at firms that are monitored under particular priority based on previous non-compliance. This leads to the following five hypotheses:

***H3a**: System revisions find more violations*

The thorough and detailed system revisions uncover more violations of pollution permits than the shorter inspections.

***H3b**: Emergency inspections find more violations*

Inspections that are performed on the basis of reported suspicion or in the case of accidents, so-called emergency inspections, are more likely to uncover violations than inspections.

***H3c**: Other controls find more compliance*

Other controls, including letter controls, random sample tests, noise controls and emission measurements, uncover few violations compared to inspections.

***H3d**: More items controlled find more violations*

Controls that investigate more than five items during a control more often reveal non-compliance than controls that investigate fewer items.

***H3e**: Particular monitoring leads to compliance*

Previous offenders that are placed in the monitoring category with particular priority, are more likely to comply with pollution permits in the succeeding control than firms under normal monitoring.

iii. The period in which the control was performed

We also find that change in compliance over time is of interest. The time or period in which the control was performed may have an impact on the outcome in form of compliance, repeated violations or the severity of the infringement. Here, we distinguish between the aggregate effect on compliance for the entire period, and the short-term effect of the period around the financial crisis. We postulate the following three hypotheses:

***H4a**: Compliance increase as technology improves*

Compliance increases over time as there is an increased focus on environmental impact, and improvements in technology that will lead to lower marginal abatement costs.

***H4b**:* *Compliance decrease after the financial crisis*There is a decrease in compliance in the period between 2006 and 2011, compared to the period before the early onset of the financial crisis.

H4c: *More repeated offenders after 2005*
Firms are more likely to have consecutive violations in controls performed after 2005 than controls undertaken before the early onset of the financial crisis.

Additionally, by examining the findings from the hypotheses above, we are interested to see whether there is evidence of what is argued in much international literature; that there is a higher compliance rate than anticipated by rational crime theory. This predicament, denoted as the "Harrington paradox", has been widely discussed within the literature with various evidence (Harrington, 1988; Heyes & Rickman, 1999). We will therefore conclude with a discussion on whether there is evidence of a "Harrington paradox" among Norwegian firms.

Lastly, we have to consider the possibility that there are undetected violations, as the majority of firms with permits are not monitored each year. We do not intend to answer whether these are intentionally concealed, or if firms are speculating in breaking the law for economic gain.

1.2. Outline of thesis

In Chapter 2 we will present the Norwegian permit system, and provide an overview of the regulatory environment. Here, we will look at how permits are distributed, NEA's monitoring process and the corresponding enforcement measures. In Chapter 3, a literature review of the theoretical framework that is used in the analysis will be introduced. Here, we will present research on compliance, monitoring and enforcement in regards to environmental regulations. The literature discusses the issues of asymmetric information in the principal-agent model and the efficiency of pollution instruments. Further, we will in this section review Becker's model (1968) on rational crime theory, as well as the opposing "Harrington paradox" (1988). The applied method will be presented in Chapter 4, along with a description of the data, econometric models and variable construction. In Chapter 5, we will present the econometric analysis and discussion of the results. Chapter 6,will provide a conclusive note, while policy implications, limitations and suggestions for further research are included in Chapter 7.

2. BACKGROUND

Public policy that aims at reducing pollution can be divided into two types, direct and indirect regulations. Direct regulations, referred to as command and control instruments, set specific restrictions to the firm. The use of direct regulation entails technology restrictions and requirements for production and cleanup processes. This type is most commonly used through permits, which we will be examining in this thesis. Most economists, on the other hand, generally favor indirect regulations such as taxes and tradable quotas. These are market-based instruments that work by altering the structure of payoffs that firms and individuals encounter (Perman *et al*., 2011).

These two forms of regulation, direct and indirect, often complement each other in the creation of an environmental policy. The identification of appropriate pollution instruments is a merit of careful consideration. In Norway, a combination of instruments are used to implement action to reduce pollution, such as the European Union (EU) emission trading scheme, environmental taxes, direct payments to Norwegian farmers, transport taxation and increased use of biomass as an energy source (OECD, 2011; State of the Environment Norway, 2015). As of today, there is a well-established permit system, with substantial monitoring and enforcement data on Norwegian firms. An overview of literature on the effectiveness of these permits will follow in *Section 3.1*.

2.1. The Norwegian permit system

On the basis of the European Economic Area (EEA) agreement, Norway's environmental policies are substantially influenced by the EU. As a consequence, environmental and climate policies of the EU are incorporated in Norwegian laws. Because of Norway's close proximity to other European countries, it is in Norway's interest that the EU follows strict environmental regulations, and that close cooperation is consolidated in the EEA agreement (Ministry of Foreign Affairs, 2013). Nevertheless, according to the OECD Environmental Performance Review, Norwegian regulations are more stringent, especially in terms of environmental permitting. The report also states that "enforcement is better targeted, risk-based and deterrence oriented" within the Norwegian system (OECD, 2011).

The Norwegian Government, in combined effort with the Parliament, decides the level of ambition for environmental policies in Norway. Further, the Norwegian Ministry of Climate and Environment is the main authority and holds the responsibility of ensuring integrated governmental climate and environmental policies in Norway (Ministry of Climate and Environment, 2014c). Beyond the jurisdiction of the Ministry, the system is decentralized in the sense that environmental responsibilities are levied to the county and municipal levels.

The foundation of the Norwegian regulatory scheme is based on the polluter-pays principle, and the importance that policy instruments meet the criteria of efficiency and cost-effectiveness. Environmental policies are constructed based on the notion that those who produce the pollution should also carry the cost of cleaning, thus being responsible for the damage caused to the environment and human health (NEA, 2015a; Walle, 2003).

2.2. The Norwegian Environment Agency

The main executional and regulatory body is the Norwegian Environment Agency, *Miljødirektoratet,* also referred to as NEA. The agency is under the Ministry of Climate and Environment and is a merger of the former Norwegian Pollution Control Authority (NPCA) and the Norwegian Directorate for Nature Management (NEA, 2015a).

> "Our principal functions include monitoring the state of the environment, conveying environment-related information, exercising authority, overseeing and guiding regional and municipal authorities, cooperating with relevant industry authorities, acting as an expert advisor, and assisting in international environmental efforts."
>
> - The Norwegian Environment Agency (NEA, 2015a)

NEA has been assigned key tasks with the intention to achieve the national objectives set by the government and parliament. Among the variety of responsibilities, the agency's executive tasks include monitoring air and water pollution, issuing pollution permits and enforcing that these are upheld. This work is performed in unison with the county governor and the local municipality (NEA, 2015a).

Every year, NEA receives an allocation letter from the Government and the Ministry, which serves as a one-year contract between the Ministry and the agency. In this document, NEA receives their assigned budget that should correspond with the set performance requirements, guidelines and focus areas that the agency is required to prioritize for the coming year. According to the allocation letter, the national objectives that are set by the ministry in Proposition 1S (2014-2015) are of political character, subsequently the burden to fulfill national goals should not be carried by any independent agency. Moreover, NEA holds the freedom of operations in the sense that it is the agency itself, based on their expertise, that decides and plans for monitoring and enforcement for the coming year (Ministry of Climate and Environment, 2014b).

2.3. The Norwegian Pollution Control Act

The Norwegian Pollution Control Act of 1981, *Forurensningsloven,* was implemented with the intention of protecting the environment by limiting pollution and waste. The law states that all pollution that causes damage to the environment is prohibited unless an exception is specified. "This wide definition means that at the outset, practically any emission is illegal" (Nyborg & Telle, 2006). The Act is administered by the Ministry of Climate and Environment, and it is the Ministry in conjunction with NEA that holds the pollution authority on a national level. On the county level the jurisdiction is held by the Ministry or jointly by the county and county governor. At the more local level, it is the municipality that holds the decision power (Norwegian Pollution Control Act, §81).

To fully understand the implications of this act, there must first be an understanding of how the term pollution is defined. The act states that pollution includes the "introduction of solids, liquids or gases to air, water or ground, noise and vibrations, light and other radiation to the extent decided by the pollution control authority, and effects on temperature which cause or may cause damage or nuisance to the environment", as well as anything that can aggregate previous damage or combined with the above mentioned cause damage or nuisance (Norwegian Pollution Control Act, §6). What is considered to be ordinary pollution from schools, hotels, office buildings, private households, fisheries, agriculture, forestry and temporary construction activity is excluded from the prohibition as long as no special regulations have been issued, and pollution from individual means of transportation is covered by different legislations (Norwegian Pollution Control Act, §5, §8).

The Pollution Regulations, *Forurensningsforskriften,* is a provision of the Act, where the regulations relating to pollution control are further outlined, such as detailed information about fine levels and the application process (Norwegian Pollution Regulations, 2004).

2.3.1. Permits

Originally subject to the no-pollution legislation, firms are depending on pollution permits in order to attain a government-controlled exception from the Pollution Control Act. Today, there are issued 4 327 plant-specific pollution permits across all sectors, where 1 185 are issued to firms that operate in land-based industry and 84 permits are issued to offshore plants (NEA, 2015b). These permits may specify maximum pollution levels in accordance to the specific firm and its industry, but can also demand qualitative measures within the firm. One of the most common requirements made to firms is the implementation of audit systems and internal routines to monitor their own environmental performance. These permits are thought to improve overall environmental performance by imposing firms to monitor, track and manage their environmental impact. Qualitative measures are also easier to validate by inspections as these can be visible through the firm's precautionary initiatives. Maximum level of pollution, on the other hand, is difficult to measure due to the stochastic nature of emission (Nyborg & Telle, 2006).

2.3.2. Firm Classifications

In order to dispense pollution permits, and later inspect the adherence to these, NEA has a classification system that categorizes firms based on industry, type of pollutant, level of emission, nature of the recipient and vulnerability of the surrounding environmental habitat.
A firm's risk class is determined in the application process and specified in the granted pollution permit. The classification can be changed according to §18 in the Norwegian Pollution Act (Klemetsen, 2015).

The firms are divided into four classifications based on the pollution threat. Risk class 1 is the strictest classification and consists of firms with the highest risk of pollution, while risk class 4 is considered to be firms with lower potential pollution levels. Table 2.1 illustrates the specification system that NEA uses.

Table 2.1 Risk classification of firms with pollution permits

Risk class	Relationship between emission level and recipient	Risk class description
1	Significant emission, weak recipient Significant emission, medium recipient	Strictest risk class, highest-risk firms
2	Significant emission, good recipient Moderate emission, weak recipient	High-risk firms
3	Moderate emission, medium recipient Small emission, weak recipient	Low-risk firms
4	Moderate emission, good recipient Small emission, medium recipient	Most lenient risk class, lowest-risk firms

Source: NPCA, 1999; Klemetsen, 2015

As seen in Table 2.1 above, firms are grouped based on emission level, from moderate to significant, and the recipients are ranked as weak, moderate or good. The nature of the recipient denotes the carrying capacity of the environmental good, such as the distinction between an open ocean and a small watershed (Walle, 2003). A further specification of this can be seen in Table 2.2 below.

Table 2.2 Evaluation of recipients

Recipient	Weak	Medium	Good
Water	• Medium large waterways in general. • All small waterways. • All small “threshold fjords.” • Municipal network.	• Threshold fjords (except small ones) and closed coves. • Large waterways. • Medium large waterways without other strong interests attached.	• Open ocean and most fjords. • Large watersheds without other strong interests attached.
Air	• Closed area (e.g. bottom of valley). • High pollution load. • High frequency of still wind or strong wind from source to populated area.	• Recipient that lies between weak and good recipient.	• Open terrain. • Affects few people. • No other significant emissions. • Good air circulation (no still wind or little inversion)

Source: NPCA, 1999; Klemetsen, 2015

NEA has to perform an individual assessment of each firm to make a sensible judgment when determining the appropriate risk class. The general guidelines set by the NEA states that the assessment of emissions should take into account the actual level of emission and the potential risk of emission in case of an accident. Firms' risk management and contingency plans, *beredskapsplikt*, should therefore be included in the overall assessment. Further, if NEA evaluates different risk classes based on discrete emissions to water or air, the firm must be placed in the strictest risk class of the two evaluations. Finally, noise pollution is not included in the classification system, but should be included in the overall discretionary assessment (Klementsen, 2015).

In general, the risk of emission is considered greater in firms with large-scale industrial activities and offshore petroleum operations; therefore these types of firms are often classified with risk class 1 or 2. Firms that have been classified with risk class 1 are often large and more complex than other firms controlled by NEA. This often involves stricter requirements to the firms, and the requirements cover a wider variety of activities. The permits are modified and granted specifically to the firm based on the specific production process, waste types and industry. As briefly mentioned above, the classification can be changed according to §18 in the Norwegian Pollution Act (Klemetsen, 2015). However, from conversations with NEA it seems apparent that in practice, the licensing only changes if there are major alterations to the firms' operating conditions. Hence, firms are not continually moved from one risk class to another unless there is a significant increase or decrease in the level of emissions (NEA; Orvik, 2015).

2.3.3. Monitoring

In addition to administering the distribution of pollution permits, monitoring of firms' compliance to these is considered to be one of NEA's most important contributions to upholding the Norwegian pollution permit system.

In their strategy for inspection and enforcement, NEA has established an overview of their monitoring goals. Here, the agency emphasize their focus on risk-based inspections, better inspection results, swift and decisive action against severe deviations and good inspection expertise. To achieve this, NEA has created several points of priority to follow in their monitoring work (NEA, 2013).

Each fall, NEA forms a monitoring plan for the coming year according to the allocation letter from the Ministry. The control frequency is pre-determined, displayed in Table 2.3 below.

Table 2.3 Monitoring frequency

Risk class	Freq. inspection *	Freq. system revision
1	Each year	Every 3rd year
2	Every 2nd year	Every 6th year
3	Every 2dn/3rd year	-
4	When needed	-

Source: Klemetsen et. al, 2013
* Frequency of inspections can deviate from the schedule when violations are detected.

The controls are risk-based, meaning that firms with the assumed highest likelihood of non-compliance are prioritized when controls are planned. The potential consequences of non-compliance are also factored in, meaning that firms are prioritized when the risk of severely damaging the environment is high if violations were to exist (Nyborg & Telle, 2006; Klemetsen *et al*., 2013).

Even though controls are based on these pre-determined frequencies, the agency has to take a wide variety of information into consideration in order to construct a monitoring schedule, and chose a theme for the controls. The plan for the following year is based on studies done within the agency, as well as research from external sources. In addition, the agency has to consider experiences from previous inspections, including observations made by the county governor. Lastly, the yearly monitoring plan will include changes in existing laws, as well as the incorporation of new regulations (NEA; Orvik, 2015).

In cases where new regulations are implemented, NEA's procedure is to control these quite promptly. In addition to the regular monitoring schedule, NEA emphasizes the importance of a regulatory presence, which entails the possibility that all firms with pollution permits may be audited. In practice, this means that even firms with the lowest likelihood of pollution, such as firms in risk class 4, should know that there is a chance that their permits will be controlled (NEA; Orvik, 2015).

Even though NEA is the governing agent with power to economically sanction firms, the agency wishes to have a good dialogue with the inspected firms. Their focus during inspections is to achieve a process where collaboration and communication is essential, and where the agency and the firms work together to achieve desired results (NEA; Orvik, 2015).

The NEA uses a wide range of approaches to ensure that controls detect all possible errors and deviations effectively. These are not only meant to detect violations, but also to verify information the firms themselves have provided. NEA's monitoring methods can be divided into four main categories: inspections, system revisions, emergency inspections and other controls. Methods that are commonly used during several of these control types include examination of logs and other documentation, visual verifications, random sample tests, and controls of routines and instructions for reporting. Although there are different structures of the controls, they are all based on the principles of the ISO 19011 standard, which consists of guidelines for revisions and audits of management systems (NEA; Orvik, 2015; ISO, 2015).

Inspections

Inspections are brief and in some cases unannounced controls that are conducted in one day or less. The unannounced controls are performed to vindicate the legitimacy of the inspections, as well as to maintain the integrity of the government. As a control agency, NEA holds a responsibility to be an objective representative to the local community, general public, non-governmental organizations and other stakeholders (NEA; Orvik, 2015). These controls will check specific requirements from the pollution permit, and will also assure that the firm has eliminated potential deviations or remarks from previous controls. Waste management, the production process, and handling of chemicals may also be controlled. The theme of these controls is determined in the yearly monitoring plan, and the above mentioned factors such as risk assessments, previous supervisions and current focus areas of NEA are contributing elements in the process (Walle, 2003).

System revisions

System revisions are longer lasting controls, ranging from one to three days. Due to the complexity and duration of these controls, they are announced in advance and scheduled with the firm. The revisions are performed in collaboration with central employees at the controlled unit, and interviews are also conducted. These revisions perform a detailed review of the environmental management system as well as the internal control system. Instructions, processes and routines are thoroughly inspected (Orvik; NEA, 2015a).

Emergency inspections

When receiving reports about violations or particular suspicion, NEA performs emergency inspections. The purpose of these controls is to gain an understanding of the actual situation and gather evidence if there are deviations from the permit, and if criminal activity has indeed occurred. Emergency inspections are always announced (Walle, 2003).

Other controls

Other controls is a grouping of all tests and controls that are not included in other categories. This includes random sample tests, emission measurements, noise controls and letter controls. Along with Kjetil Telle from Statistics Norway, NEA has tested the effectiveness of issuing warning letters in the wake of controls. Their experience suggests that letter controls indeed are taken seriously by the firms and have incentivized correcting behavior (NEA; Orvik, 2015).

All these four monitoring methods will end with a verbal notification of the control results. Here, the agent from NEA, or county-governor, will along with the firm representative agree on the terms of the control, as well as the conditions revealed. Further, NEA sends out a written report of those issues that have been revealed, number of violations and deviations given in the control (Walle, 2003).

In addition to the above controls performed by NEA, self-reporting is required for firms in risk class 1, 2 and 3. The responsibilities of the firms are outlined in a publicly available guide to self-reporting issued by NEA (2010). Self-reported results are considered irrevocable and legally binding at the same level as results from controls performed by NEA or the county governor.

2.3.4. Enforcement and penalties

In line with the collaborative monitoring process, the enforcement and penalty philosophies are trust-based. NEA often uses informal and administrative sanctions before filing formal accusations. This includes warning letters, increased controls, coercive fines, public access to control results, police reporting, and retraction of or changes to the pollution permit. Which action is taken depends on the seriousness of the violation (Orvik; NEA, 2015a).

The severity of the violation is decided after the performed controls and evaluation of self-reported results from the firms. NEA divides the detected issues into two categories; deviations, *avvik*, and remarks, *anmerkninger*. Deviations are defined as "failure to comply with the requirements established by law", while remarks are defined as "conditions that are not covered by the definition of deviations, but that the supervising authorities find necessary to point out to protect the environment" (NPCA, 2001). Remarks are not considered a violation per se, but rather functions as a comment on deficient routines or procedures, while deviations are considered violations of the issued permit and the law. Deviations are not limited to cases where firms exceed the permitted emission levels, but also entails failure to comply with qualitative demands. Especially critical violations are labeled as severe deviations.

When violations are detected, firms are usually issued a warning and a time period to solve the problem without other sanctions (Walle, 2003). Major violations, on the other hand, often cause immediate reactions. In the strategy for enforcement and inspection, swift and decisive action against severe deviations is a focal point (NEA, 2013). When a violation is deemed a severe deviation, NEA will consider legal action. Even when a legal claim is filed, NEA will continue their inspection of the incident parallel with the police investigation. The criminal case will be police responsibility, while NEA continues with the means they have available, such as coercive fines, letter controls and additional monitoring. This leads to a double burden for the firm. When a case has been reported to the police, NEA will avoid taking the case to the media, so they are sure not to get in the way of the investigation. However, in cases that are considered serious breaches but are not reported to the police, NEA states in their enforcement strategy that they will use the media to spread the information uncovered by NEA's activities. Severe deviations will also lead to stricter monitoring in the future, to further incentivize compliance (NEA; Orvik, 2015). The intensity of monitoring is categorized into four categories shown in table 2.4.

Table 2.4 Monitoring categorization of firms with pollution permits

Category	Description
0	Should be monitored less frequently
1	Should be monitored normally, according to routine
1	Should be monitored with particular priority
3	Should be monitored with particular priority and legal action should be considered

Source: Walle, 2003

The categories indicate how frequent the plants will be monitored, and are based on an evaluation made by NEA based on firms' past performance and the expected risk for the particular plant in the given industry. As previously mentioned, firms with severe deviations will often experience particular monitoring.

In accordance with the polluter-pays principle, firms are responsible for covering the costs of controls. Applying firms also have to pay fees to cover the work of forming new permits, and the firms are also financially responsible to cover the cost of changes to existing permits. They are given a 30-day period to pay the bill, which is issued when the audit report is sent from NEA to the firm (Norwegian Pollution Regulations §39, 2004). The income from these controls go directly to NEA's monitoring budget, and is used to cover costs of controls.

The price of the extensive system revisions is calculated independently from risk class. The price is based on the cost of the control, such that the firms are divided into the four fee rate classifications in Table 2.5 on basis of NEA's calculated use of resources during revisions. This is decided in an individual assessment for each firm (Walle, 2003).

Table 2.5 System revision costs

Fee rate	Revision price (in NOK)
Rate 1	223,500
Rate 2	142,600
Rate 3	84,800
Rate 4	47,100

Source: Norwegian Pollution Regulations §39-8

The prices of inspections and the fine levels are fixed within each risk class, as seen in Table 2.6. The prices of inspections are much lower than those of system revisions. As the frequency of controls is higher in the high risk classes, firms in these categorizations will not only pay higher fees per control, but face much greater abatement costs over time.

Table 2.6 Inspection price and fine warnings

Risk class	Inspection price (in NOK)	Fine warning* (in NOK)
1	21,100	0 – 1,000,000
2	15,900	0 – 500,000
3	12,200	0 – 250,000
4	4,700	0 – 50,000

Source: Norwegian Pollution Regulations §39-6; Klemetsen et al, 2013
* From 2012. Based on evaluation by NEA officer. Rarely as high as max.

If a control detects violations, NEA issues a letter with a fine warning that the firm will have to pay if the violation is not corrected. The level of the fine warning is set by an NEA officer based on his or her evaluation of the violation. However, the fine is rarely set as high as the maximum limit (Klemetsen *et al*., 2013).

2.3.5. Political influences

Beyond the allocation letter received from the Ministry of Climate and Environment, there are additional political factors that could possibly affect NEA's monitoring methods. As previously mentioned, the EEA agreement entails that the EU substantially influences Norway's environmental policies. In some areas, NEA operates differently compared to other European agencies. This specifically relates to the philosophy surrounding monitoring and enforcement. Here, the agency expresses that there are some differences, both culturally and principally, in the methods that are used for administering and overseeing pollution permits within the EU and in Norway. In Norway, monitoring of pollution permits is built on mutual trust, cooperation and open dialogue between the agency and the inspected firm, where there is a clear governmental presence but without forced power (NEA; Orvik, 2015).

In terms of the political influence on NEA's monitoring methods, there is a recent push from the IEEP to impose more frequent controls, unison revision guidelines and more rigid penalties across Europe, expanding beyond the EU to include countries in the EEA agreement. NEA has expressed some concern with a standardized inspection format on the basis of conflicting monitoring methods. Within the EU there are political inconsistencies, and the incorporation of these policies into the Norwegian framework could pose great challenges. Although member states within the EU are given the independence to construct domestic methods for monitoring, reporting and verification, this is not the case for the enforcement of these. Further, many of the member countries have different authoritative cultures, and perhaps weaker institutions. When the EU imposes strict enforcement demands to the member states, such as non-flexible high penalty for non-compliance, it may lead to a less effective policy (Kruger *et al*., 2007). This could potentially be a bad fit with the current Norwegian model. If these rules were to be applied within the EEA, and consequently Norway, then the NEA would be forced to implement harsh penalties, and rigid enforcement systems.

Further, the IEEP is interested in an increased frequency of controls whereas NEA holds quality of controls, rather than quantitative measures, in high regard. NEA requires their inspectors to have strict qualifications to ensure that controls are properly and thoroughly executed. In addition, the agency is very careful in their monitoring when it comes to excluding monitoring errors; if there is any doubt, the firm will not receive a warning or deviation from the existing permit (NEA; Orvik, 2015). The recent push from the EU that there should be a standard format for environmental regulations across Europe is problematic to NEA due to fundamental differences in approaches in monitoring and enforcement methods. NEA relies on a trust-based monitoring system that includes user-oriented methods that encourage dialogue with firms, rather than forced power. (NEA; Orvik, 2015).

3. LITERATURE REVIEW

3.1. Informational issues

An environmental regulatory agency such as the NEA will, in practice, find itself in a position of having to make decisions based on restricted information. Theory implies that when two players act together where one holds information (the agent) and the other does not (the principal), a principal-agent model is created (Rasmusen, 1989). Here, Cohen (1987) states that the benefit of looking at compliance with environmental regulation in a principal-agent framework is that it can be helpful when modeling relationships that implicate incentives and risk sharing. The principal-agent model introduces the issue of asymmetric information where the principal, the regulator, has less accurate information about the agent's internal actions than the agent itself. The principal's lack of information specifically relates to the agent's perception of risk, and the costs of complying with the regulation.

There are two standard models within this framework. The moral hazard model states that the regulator cannot fully observe the action taken by the agent, that is to say that the principal has problems revealing if the agent actually is in compliance with the proposed regulation, which could lead to wrongful findings. Thus, the ex-post moral hazard includes making a type II error. The adverse selection model looks at the difficulty for regulators to observe the agent's hidden characteristics, such as firms' true marginal costs. Moral hazard and adverse selection often arise when the regulator does not successfully manage to incentivize the agent to reveal true information. A pollution mechanism that is not efficient can lead to a situation where the agent is led to engage in manipulative behavior by withholding information or claiming to be in compliance when in fact, they are not (Rasmusen, 1989; Romstad, 2005).

Laffont (1995) explores the contradictions between cost minimization and level of risk taking. This relates to the issue of moral hazard, and the temptation to engage in "manipulative behavior", as stated by Romstad (2005). In his article, Laffont discusses the potential trade-off to a firm when the focus is to minimize cost while being faced with regulatory demands, thus potentially leading to ex-ante moral hazard of increased risk-taking. Here, he uses the Exxon Valdez oil spill as an example to illustrate that agents are carrying responsibilities that can cause large hazards to the environment, and society as a whole. This entails the lack of care, poor safety routines or external pressures to deliver on time and minimize cost. In his rather complex model, he concludes that the protection of large environmental risks cannot be left to the market, and a high level of coordination is needed to ensure that firms are not taking on too much risk (Laffont, 1995).

It is well known that regulatory enforcement is difficult for a variety of reasons, as stated by a large body of literature (See Heyes, 2000; Shavell, 1986 for a review). Heyes states that it is troublesome to know true compliance rates with any certainty due to the nature of the regulatory requirements. He specifies that one should interpret compliance statistics with care due to the fact that government agencies sometimes categorizes firms and the polluting source as compliant, when in reality, the agency simply fail to demonstrate non-compliance (Heyes, 2000). Russell (1990) discusses in his study cases where estimates of compliance rates can be untrustworthy. Here, Russell points to the hazardous waste regulations in the US where he asserts that the EPA's documentation of non-compliance is ".. largely a catalogue of speculations about the possible extent of illegal disposal" (Russell, 1990; p.261). However, Heyes argue in a previous study that by increasing the thoroughness of the controls, it can induce firms to substitute towards more transparent technology. This specifically relates to the monitoring agency's equipment, and that these are of such standard that reduces inaccuracy (Heyes, 1994).

When pollution is stochastic, meaning that there is an irregular occurrence of emission, and NEA does not have full information about its source or size, the type of monitoring and enforcement strategy is especially important. Further, Heyes (1998) argue that thoroughness of inspection has a better effect on firms' environmental performance rather than an increased frequency in controls. The methods NEA has at hand must be evaluated on the basis of their productive capacity. As mentioned in section *2.3.3 Monitoring,* the agency holds quality and diligence of controls in high regard, and all inspectors are required to meet strict qualifications. As monitoring equipment is better, and the methods for inspection are more rigorous, it may ensure that firms' actions become more transparent and that the firms engage in less "manipulative behavior."

Regulations should create incentives for firms to disclose information. The question that arises is how the regulator can create effective policies while having imperfect information. In terms of command and control instruments such as non-tradable pollution permits, asymmetric information can lead to difficulties for the regulator when monitoring and enforcing the regulation. Because firms may indulge in manipulative behavior, it is according to much literature even more crucial that the monitoring frequency is right and that inspection standards are upheld with a rigorous hand.

3.2. Effectiveness of pollution control instruments

NEA claims that cost-effectiveness and efficiency are important criteria in their permit system (NEA, 2015a). However, most economists tend to favor market-based instruments like indirect regulations to achieve this. According to standard economic theory, indirect regulations such as tradable quotas, green taxes and subsidies are considered more efficient and cost-effective than direct controls because they create incentives to the agent to voluntarily change behavior, while doing so in the least-cost manner. Hence, market-based instruments encourage firms to find the least-cost way of abating at the margin, while achieving the level of desired environmental quality. This often entails investing in technological advancements (See Tietenberg, 1990; Stavins, 1995).

Nevertheless, there are also other measures to evaluate environmental policies by than efficiency and cost-effectiveness. Hahn and Stavins (1992) state that other important factors include ease of implementation, monitoring and enforcement capability, clarity to the public and not the least, political feasibility. Despite the various literature on cost-efficient emission reduction, direct regulation may have appealing effects such as "the power to get results quickly and provide certainty of outcome, although not always in the most efficient way" (Perman *et al*., 2011). Pollution permits might be especially preferable for highly localized pollution problems, where source-specific criterions may be necessary. In terms of the efficiency issue, this especially relates to the transaction cost of ensuring compliance through monitoring and enforcement (Hahn & Stavins,1992).

Klemetsen *et al*. (2013) extends the argument for non-tradable pollution permits by claiming that this type of regulation can, despite what general theory claim, create incentives to the firm. In their paper they investigate Norwegian panel data on non-market regulations and whether these can spur innovation in environmental technologies. They measure environmental innovation as the type and number of patent applications of environmental significance. Patent has been used as a measure in other empirical studies as well (see Dechezleprêtre et.al, 2011). In their article, Klemetsen *et al*. results suggest that there is an incentive for firms to invest in new technology and that this arises from the probability of being sanctioned, that is the total expected penalty, and not simply from being inspected.

In order to incentivize firms to comply with the law, and not emit more than the received pollution permit, the government threatens to sanction firms through fines, permit withdrawal or possibly prosecution. These sanctions can indirectly result in negative publicity to the firm. While market-based instruments such as pricing and indirect regulations generally are considered first-best policy instruments, Klemetsen *et al*. provide new evidence that pollution permits give an incentive to the firm through threat of sanctions, rather than as a result of other regulatory costs, such as increased inspection frequency as the polluter pays for monitoring cost (Klemetsen *et al*., 2013).

3.3. Rational crime theory

Within the literature, there are contrasting opinions on what motivates firms, and individuals, to comply with environmental regulations. Knowledge about the ways in which firms think and make decisions about compliance is essential when building an environmental regulation and designing effective enforcement systems (Winter & May, 2001). General assumptions about rational behavior would lead us to think that firms comply with regulations based on fear of being caught violating them, and consequently the punishment that follows.

Rational crime theory has been linked to violation of environmental regulation, and can give some insight to why firms are in non-compliance. Becker (1968) constructed a model that showed that an increase in penalties will reduce the total benefit by committing a crime, thus lead to less violations of the law. The main point of Becker's model is to prove that when compliance costs are higher than the expected penalty, the firms will have an economic incentive to violate the law. As a result, one could claim that the certainty and size of the fines and the monitoring frequency, i.e. the likelihood of being caught, affects the motivation for compliance (Becker, 1968).

Becker's model has some limitations, especially when he assumes that the firms are risk-neutral, as well as the intuition that all violations that are discovered will be penalized and that there is no probability of wrongful conviction. The model is static, which indicates that the results of previous controls will not affect future sanctions if violations are detected. Further, Becker assumes that the firm is cost minimizing and he treats the penalty function as just another expense to the firm. Many of these assumptions were made to simplify the model, and make it hold. Several authors have attempted to change the assumptions in order to explain the model. One of the critiques that have been prevalent is the fact that the model is static, and does not consider previous behavior. This can not be considered a very realistic assumption, since it assumes that a firm only has two choices; to comply with the regulation or to violate (Becker, 1968; Heyes, 2000; Walle, 2003).

Harrington on the other hand, developed a theory that conflicts with Becker's model. Here, he attempted to examine how firms in the US responded to environmental regulations by including a dynamic perspective where previous behavior was taken into consideration. In the article "Enforcement leverage when penalties are restricted", he proposed that firms will not be induced to comply if the probability that a violation will be sanctioned is low. Harrington's much discussed paper starts by making three statements; (i) For most cases the monitoring frequency low, (ii) Even when violations are discovered, fines or other penalties are rarely assessed and are small compared to the cost of complying, yet (iii) It is still evident that firms comply most of the time (Harrington, 1988; p.29). Here, Harrington defines a low monitoring frequency as 1-2 controls per firm each year. One of the assumptions for Harrington's model is that there is little asymmetric information between the agent and the principal. This would entail that the firm knows what methods the regulator uses and how they are classified by the agency, and the regulator knows the firm's individual cost of compliance (Harrington, 1988; Walle, 2003).

A note to be made is that most of Harrington's paper is based on previous studies in the US. Many authors have argued that the "Harrington paradox", as it was labeled by Heyes and Rickman, is based on little empirical evidence, and Cohen goes as far as to call it "stylized facts" (Cohen, 2000; Heyes & Rickman, 1999; Heyes, 2000;). Despite the theoretical focus of Harrington's paper, other authors have repeatedly used his points as though they proved sound empirical evidence for better firm-compliance, and consequently greater environmental performance, than what is stated in rational crime theory.

Many authors have examined Harrington's statements and Becker's model of rational crime to explain firms' behavior and motivations to comply with environmental regulations. Nonetheless, it is important to consider the likelihood that real compliance decisions are continuous by nature. As discussed in Heyes article (2000), Viscusi and Zeckhauser (1979) did a notable study on compliance with industrial effluent standards. In this study, they argue that when permit standards are raised, some firms will violate rather than pay the increased costs of higher technological standards. The authors claim that once the decision to not comply has been made, the extent of the violation will depend on the magnitude of the increased fixed costs. Further, the authors claim that firms may have incentive to provide at least some fraction of what the regulatory agency wants (Heyes, 2000). This is, according to Shavell (1992) the "principle of marginal deterrence". By ignoring to understand this concept, one can justify many of the apparent paradoxes of observed behavior from previous studies (see Harford, 2000; Harrington, 1988). For example when Harrington claims that the penalty should be restricted, it indicates that raising the level of penalties may worsen compliance, which in return contradicts the "principle of marginal deterrence" (Heyes, 2000; Shavell, 1992). As an example, if a firm was given the same punishment for a severe violation such as dumping hazardous waste into the sea as for the less serious violation of poor internal routine when managing waste disposal, the firm could make the "rational choice" of always dumping the waste in the sea because it would give the same punishment, and ensure a lower cost. Thus, it is crucial that the regulator understands that firms have to make continuous decisions where the dynamics of incentives, such as increasing penalties with the severity of the violation, can affect the level of compliance and the persistence of consecutive violations, as well as the severity of these.

In all, monitoring and enforcement methods have a large effect on compliance. A better understanding of both the general effectiveness issues at hand and the nature of the relationship in a principal-agent model, including issues of moral hazard and adverse selection, is crucial for a well-functioning environmental regulation. Although we are looking at compliance from an economic perspective, there are other theoretical foundations that look at factors of deterrence. Nyborg (2003), among others, include the aspect of social norms when firms make decisions about complying with environmental regulations. In addition, several authors have mentioned commitment to social norms, moral reasoning and knowledge of rules and technologies when discussing whether firms comply with environmental regulations (See Burby & Paterson, 1993; Scholz, 1984). An interesting study on social norms and environmental compliance behavior is found in an article by Winter and May (2001). Here, the authors use a logistic regression to examine Danish farmers' compliance to agro-environmental direct regulations. Their findings reveal that awareness of rules plays a critical role in compliance. Further, they argue that normative and social motivations are as influential as calculated financial motives in avoiding violations. The findings from this study concludes that formal monitoring systems with strict routines and trust-based inspections can be helpful, while coercion or use of force in monitoring methods can have an unfavorable effect (Winter & May, 2001).

It seems evident that there exists contrasting beliefs as to what motivates firms to comply, whether it is when the expected penalty is lower than the cost of compliance (Becker, 1968) or that firms actually comply at a much higher degree than predicted by rational crime theory (Harrington, 1988). Nyborg and Telle argue that, from the Norwegian data on permits, there is little evidence to confirm Harrington's statement about paradoxically high compliance rates. However, the authors point out that without the marginal abatement cost, one could only hypothesize about the expected effect (Nyborg & Telle, 2006). It could be argued that without the actual costs of complying, which neither Harrington nor Nyborg and Telle had data on, the studies will have obvious limitations, and provide little empirical evidence. This is the case for many studies on compliance with environmental regulations, specifically where command and control instruments have been applied.

4. METHOD

In order to investigate those factors that might affect Norwegian firms' level of compliance to pollution permits, this thesis uses three logit models to analyze panel data on firm characteristics and monitoring methods used by NEA in the period 1997 - 2011. The logit models will be run on different data sets. We will focus on two industries, oil and gas versus land-based industry. Each data set will be tested with several model estimations in order to see which variables are significant predictors, and to what extent these affect compliance, consecutive violations and the severity of the deviations.

4.1. Data collection and description

All plant-specific panel data is obtained from NEA. In addition, several data sets have been received from Marit Klemetsen at SSB, with the approval of NEA. These refined data sets were originally acquired from NEA's raw data, and have been integrated into the compiled data set. In total, the raw data contained over 5000 observations that span 21 years, from 1993 to 2014. In order to obtain similar variables for all observations, several of the data sets were merged using the plant- and organizational number as the firm identifier. The data includes controls of pollution permits for several plants collected over a number of years with firm as the same cross-sectional unit. The initial data set contained plant number, control year, control type, organizational number, number of deviations and remarks as well as monitoring classification. The data set was supplemented with the assigned risk class for each firm, monitoring classification, and whether the plant belonged to land-based industry or the oil and gas sector. In order to get an equal number of observations with the same predictors, the data was merged so that no models contain missing values.

Controls performed in the periods 1993-1996 and 2012-2014 are omitted. The first period from 1993-1996 is removed due to homogeneous data. In this period, only 1 of the 324 controls detected and registered firms in non-compliance. The skewed data might be a result of structural changes within NEA's monitoring methods, or because of severe changes in regulation requirements. For the period 2012-2014, observations are omitted due to inadequate data from NEA. The observations for this recent period are all controls from the offshore industry, and

there are only 27 observations. The concern is that the results from this period will give a misrepresentation in the analysis, as years and periods are included as explanatory variables. They will therefore be excluded. These reductions resulted in the key data set for our analysis, which contains 1 602 controls performed at 447 different firms.
It is evident that we have unbalanced panel data, where the number of observations has not been the same for every plant. This entails that although there are observed controls for each plant, the number of controls and the interval between these vary between firms.

4.1.1. Weakness of data

There are several limitations of substantial impact in the available data. Firstly, controls are not conducted on an annual basis, but are rather performed at different intervals depending on assigned risk class, chosen focus for the monitoring schedule and other arbitrary judgments made by NEA. This leads to an issue with dependencies in the sample due to the unbalanced panel data. Since the same firms are controlled over time there can potentially be a correlation between the controls performed within the same company, as well as large differences in number of observed controls for different firms. Due to these issues, a limited number of controls will also be tested, where the selection includes the latest control from each firm, exclusively. In deciding how to limit the data to one observation per firm, several methods were considered. Furthermore, all data manipulation of this kind means that one has to make some general assumptions. As a result the selected method will have some weaknesses. We want to analyze the most recent firm-behavior, and have therefore decided to include the latest performed control for each firm. It is difficult to guarantee that the latest control will give a good representation of any given firm over time. Nonetheless, we have to keep the issues of this method in mind during the analysis and interpretation of the results. The model estimations for testing the sample 'latest control' might provide results that are not representative.

Secondly, the available data only includes observations from the land-based industry and oil and gas sector. Control results from other industries, such as export and import of waste and waste disposal, are not included. Ideally for our analysis, the controls from the oil and gas sector and land-based industry are representative for all Norwegian firms, but we have to acknowledge that this might not be the case, and that inclusion of controls from other sectors would have given a more complete result. Thereby, we can not generalize based on our results. Further, there are fewer firms that operate within the oil and gas sector, leading to a much smaller sample size for this data than that for land-based industry, as the number of controls that have been conducted in oil and gas are few.

Thirdly, there is the typical issue of missing observations or wrongly reported information. Although the assumption is that all variables have been measured accurately, we have to acknowledge that in practice there will be some measurement errors in the data. When it comes to missing observations, some of our variables were missing information such that the observation in question had to be dropped. In certain cases, the variable as a whole had to be dropped from the analysis; this was due to the fact that the information was available merely for the land-based industry. As we had a small number of variables available initially, this severely limited the number of explanatory variables in our analysis. Testing of plant-specific data will be performed to analyze these variables.

Lastly, as with any econometric analysis, there is a fundamental issue of including all relevant variables and finding a true model is nearly impossible (Phillips, 1986). Due to the lack of quantitative information, not unexpectedly, there will be missing variables in our model that could be explanatory. It is common experience in empirical analysis that the data we would ideally like to include is not available. One of the main issues within the literature on monitoring and enforcing firm-level compliance is that many empirical studies lack firms individual compliance costs. Our analysis is no exception, and we acknowledge this limitation to our thesis.

Other variables we would have liked to include are firm size, either in terms of number of employees or revenue, if the firm has a department or any employee specifically in charge of environmental aspects of the business, and knowledge about the level of risk aversion and the moral motivation of firms. Because of the difficulty of obtaining information on these variables, they are not included in the analysis, despite their assumed relevance in explaining how firms react to pollution permits.

4.2. Defining the explanatory variables

Industry

As we expect there to be substantial differences between the oil and gas sector and land-based industry when it comes to compliance to pollution permits we have included industry as an explanatory variable to investigate this. The data from NEA has been manipulated such that the oil and gas classification includes land-based operational activities such as oil refinement, natural gas extraction and construction of oil rigs, whereas these types of activities normally are classified as land-based industry. This is partly to give a broader sample for the oil and gas sector, and partly because we believe the attention to the environment at these establishments are more similar to those of the offshore sector than other land-based industry. The land-based industry category contains a variety of different establishments, from road construction, maintenance of large ships to waste management and paper production. Land-based industries that have the highest potential pollution damage, designated by risk class 1, typically include the production of plastic, metal, nickel or aluminum, as well as treatment of chemical waste.

Risk class

This variable uses NEA's own classification system for monitoring of firms, which is based on the expected pollution threat and industry. The categorical variable contains 4 ranks, from the category with the assumed highest risk of polluting in risk class 1, and the least risk of polluting in risk class 4. The fine warning levels and monitoring frequency are determined according to risk class, as is the price of inspections, which is covered by the firms. The variable can be seen as a predictor of expected penalty, as it includes the probability of being monitored and the cost if caught. However, we cannot distinguish between the effect of monitoring frequency and level of economic sanctions.

Control type

This variable categorizes the type of control that has been performed, and follows NEA's own categorization of control types that is further presented in section *2.3.3. Monitoring*. The four categories are inspections, which are performed in one day or less, the extensive system revisions that among other things control management systems, emergency inspections and other controls.

Monitoring classifications

In order to create a monitoring schedule, NEA has a classification system that prioritizes controls for those firms that have not complied with the pollution permit in the past. The classification is based on recommendations from the NEA agent about future control frequency. There are four categories that rank monitoring priority, ranging from 'normal monitoring according to routine' to 'monitoring with particular priority, consider legal action.' However, the available data only contains two categories: normal monitoring and monitoring with particular priority. There were 125 controls in the data set where information on this variable was missing; these observations are omitted from the analysis.

Number of controlled items

Initially, this variable was a distinction between the different severities of violations, with each control placed in one of four categories: no findings, remarks, deviations or severe deviations. The data is categorized based on the most serious offense. The variable cannot be included in the analysis as an independent variable to compliance, because it would be a perfect predictor. Instead, the variable is included by looking solely at the number of items that were investigated during the control, regardless of the result.

Year and periods variable

The year variable is used as a continuous regressor, from 1997 – 2011. The unbalanced panel data is yet again an issue, as there are some firms with multiple controls in the same year, and other with none. This can lead to a skewed representation of the firms, especially considering that controls are risk-based and firms that are considered to be high-risk are controlled more often than other firms. Because there are large differences in the number of observations for the year variable, there is some suspicion that the continuous regressor will give an inaccurate outcome. By observing the raw data, there is a notable increase in the number of firms caught in non-compliance after 2006. The dummy variable *period* was created, with the two categories 'controls undertaken in 2005 or earlier' and 'controls performed later than 2005' to investigate this trend.

4.3. Descriptive statistics

The sample of plant-specific monitoring results include 1 602 observations of controls performed at 447 different firms. Before undertaking the econometric analysis, it will be interesting to look at the outcome variable compliance, as seen from the descriptive statistics. Figure 4.1 illustrate the total percentage of all controls that were in compliance from 1997 to 2011.

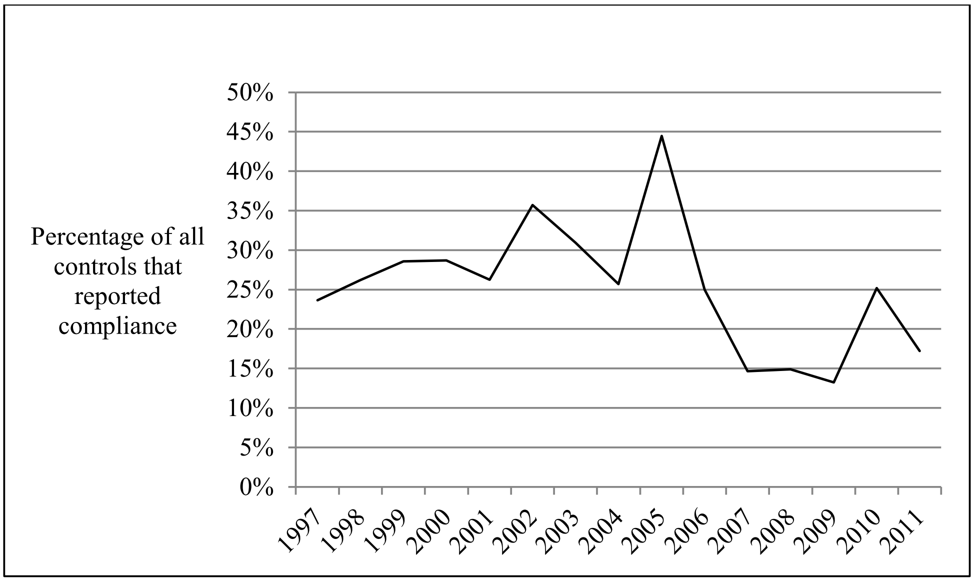

Figure 4.1 Percentage of controls that reported compliance 1997 - 2011

From a quick look at the graph, interesting observations are made regarding compliance around 2005 and 2006. We see a drastic decrease in percentage of firms that were in compliance from 2005 to 2007. This low percentage persists through 2011, with an average compliance percentage in the period between 2006 and 2011 of 18%. By solely looking at the summarized data, the best compliance performance was in 2005, where 56% of all controls revealed compliance with the pollution permit. In contrast, it is quite alarming that in 2011 alone, 83% of all plant-specific controls in the offshore and land-based industry uncovered violations. This entails that a majority of the firms with pollution permits were failing to comply with the requirements established by law.

Table 4.1 Frequency distribution of non-compliance for controls 1997 - 2011

Data selection	Number of performed controls	Controls that detected non-compliance	Percentage of controls that reported non-compliance
All controls[1]	1602	1213	76%
Latest control[2]	447	370	83%

[1] All controls performed in both land-based and oil industry
[2] Data selection including only the latest registered control per firm (one control per firm included in selection)

Moreover, as seen in Table 4.1, there is a prevalent problem with poor compliance rates among Norwegian firms. From the raw data, it is evident that the as much as 76% of all controls in the period 1997 - 2011 detect non-compliance. Nonetheless, we must keep in mind that the non-compliance rate is calculated based on all performed controls and that suspected offenders are monitored more often than other firms. Even considering this, the number of controls that detected at least one violation is very high. The high frequency of non-compliance detected in controls in this period tells us that most controls found violations, but it does not specify the number of deviations per control, nor the severity. Further, it will be interesting to look at the severity of the deviation, as well as the occurrence of consecutive violations.

Table 4.2 Frequency distribution of consecutive violations 1997 - 2011

Data selection	Number of performed controls	Controls that detected consecutive violations	Percentage of controls that reported consecutive violations
All controls[1]	1602	637	40%
Latest control[2]	447	203	45%

[1] All controls performed in both land-based and oil industry
[2] Data selection including only the latest registered control per firm (one control per firm included in selection)

Table 4.2 reports the frequency distribution of consecutive violations performed in 1997 - 2011. The raw data reveals that 40% of all controls detect repeated offenses, with two or more successive controls reporting violations.

From Table 4.3 below, we see that the percentage of controls that reported severe deviations is low compared to the overall level of compliance. Here, the raw data reveals that as few as 2% of controls detected severe deviations in the complete data set, while 4% of the controls included in the sample that includes only one observation per firm found severe deviations.

Table 4.3 Frequency distribution of severe deviations 1997 - 2011

Data selection	Number of performed controls	Controls that detected severe deviations	Percentage of controls that reported severe deviations
All controls[1]	1602	32	2%
Latest control[2]	447	17	4%

[1] All controls performed in both land-based and oil industry
[2] Data selection including only the latest registered control per firm (one control per firm included in selection)

Further, due to the difference in environmental risk related to the nature of operations in land-based industry and the oil and gas sector, we are interested in examining the distribution of firms in the two industries across risk classes.

Table 4.4 Industry-specific frequency distribution of controls by risk class

	Risk class 1	Risk class 2	Risk class 3	Risk class 4	Total
Oil and gas sector	108	5	2	0	115
Land-based industry	495	417	505	70	1487

As seen in Table 4.4, firms in the oil and gas sector are rather homogeneous when it comes to risk class, as almost 94% of the firms are placed in risk class 1. This issue of homogeneity is due to NEA's risk-based monitoring and enforcement system, where the level of environmental impact is considered when firms are assigned to the different risk classes. Due to the issue of homogeneity within the industry, we will not look at model estimations for oil and gas separately. The controlled firms in land-based industry are more evenly distributed between risk class 1 - 3, though few firms in risk class 4 have been controlled.

We are also interested in looking at the distribution of the different control types used in the period 1997 - 2011. In Figure 4.2, we see that inspections is the most performed control type throughout the period, and more than 60% of all controls in the period 2004 - 2011 have been inspections. System revisions is the second most used control, and between 20 and 30% of all controls have been system revisions in the period. Lastly, we notice that there have been fewer emergency inspections and other controls in the period 2004 - 2011.

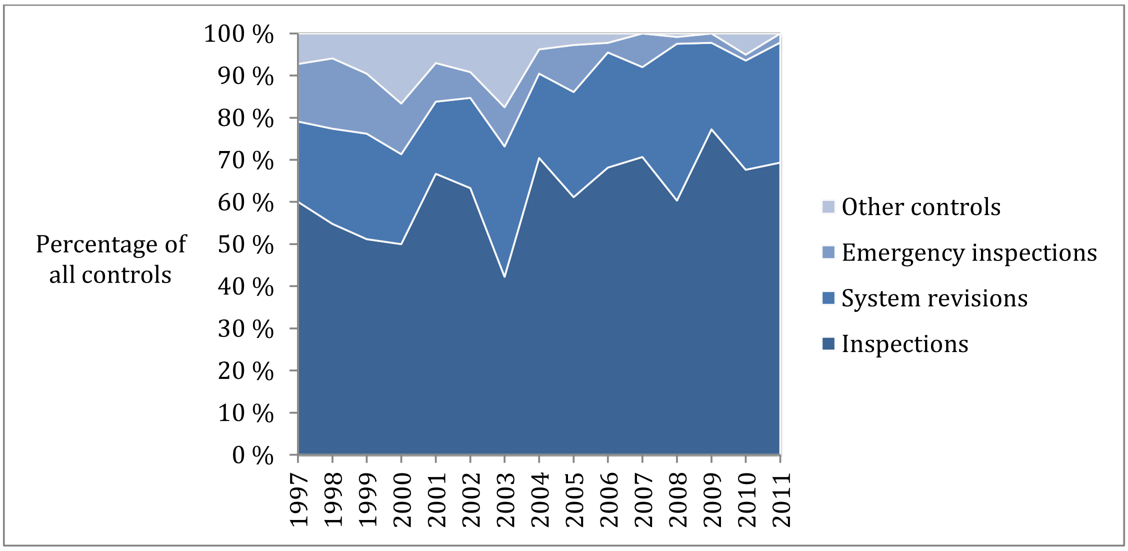

Figure 4.2 Percentage-wise distribution of control types 1997 - 2011

Before the econometric models used in the analysis are presented, a detailed description of all included variables can be seen in Table 4.5.

Table 4.5 Description of variables

Variables	Number of observations	Variable name^	Description	Mean
Dependent variables				
Compliance		COM	Dummy (0 – 1), 1 if the control does not reveal deviations, 0 otherwise.	0.24
Consecutive violations		CON	Dummy (0 – 1), 1 if there have been deviations in two or more controls in a row, 0 otherwise.	0.40
Severe deviations		SEV	Dummy (0 – 1), 1 if the control reports severe deviation, 0 otherwise.	0.02
Firm characteristics				
Oil and gas sector *	115			
Land-based industry	1487	IND	Dummy (0 – 1), 1 if the firm operates in land-based industry, 0 if the firm belongs in the oil and gas sector	0.93
Risk class 1 *	603		Reference category, high-risk firms.	
Risk class 2	422	RC^2	Dummy (0 – 1), 1 if medium-risk firm, 0 otherwise.	0.26
Risk class 3	507	RC^3	Dummy (0 – 1), 1 if low-risk firm, 0 otherwise.	0.32
Risk class 4	70	RC^4	Dummy (0 – 1), 1 if lowest-risk firm, 0 otherwise.	0.04
Monitoring methods				
Inspections *	1010			
System revisions	393	CT^2	Dummy (0 – 1), 1 if the control is a system revision, 0 otherwise.	0.25
Emergency inspections	111	CT^3	Dummy (0 – 1), 1 if the control is an emergency inspection, 0 otherwise.	0.07
Other controls	88	CT^4	Dummy (0 – 1), 1 if the control falls in the category other controls, 0 otherwise.	0.06
Particular priority *				
Normal monitoring		MON	Dummy (0 – 1), 1 if the firm is controlled according to routine, 0 otherwise.	0.90
1 – 5 controlled items *				
6 – 10 controlled items		NC^2	Dummy (0 – 1), 1 if 6 - 10 items were controlled, 0 otherwise.	0.30
10+ controlled items		NC^3	Dummy (0 – 1), 1 if 10 items or more were controlled, 0 otherwise.	0.20
Time period				
Year		YR	The year the control is performed in, continuous 1997 – 2011.	2004.67
1997 – 2005 *	857			
2006 – 2011	745	PER	Dummy (0 – 1), 1 if the control is performed in the period 2005 – 2011, 0 otherwise.	0.47

* Reference category
^ Variable name used in the econometric models

4.4. Econometric models

The binary dependent variables compliance, consecutive violations and severe deviations are estimated by the use of logit models, as seen in (1), (2) and (3) respectively. The chosen logit models use maximum likelihood in estimating the parameters.

4.4.1. Model 1: Level of compliance

When performing controls, NEA registers findings as remarks, deviations or severe deviations. Remarks are not infringements of the law, but rather comments of areas of caution. The compliance variable is defined based on the most serious violation of the control, such that a control that uncover twelve remarks and one severe deviation, will be categorized as severe deviation. This is done as we are interested in looking at firms that are in complete compliance with the issued pollution permit, meaning that the performed controls detect no deviations. For this reason, deviations and severe deviations are considered violations, and result in non-compliance. Controls with remarks are considered to be in compliance with the pollution permit, along with controls without any findings. The logit model for compliance is specified in (1).

$$(1)\quad COM_{cf} = \beta_0 + \beta_1 YR_{cf} + \beta_2 IN_{cf} + \beta_3 RC_{cf}^2 + \beta_4 RC_{cf}^3 + \beta_5 RC_{cf}^4 + \beta_6 CT_{cf}^2 + \beta_7 CT_{cf}^3 + \beta_8 CT_{cf}^4 + \beta_9 PER_c + \beta_{10} MON_{cf} + \beta_{11} NOC_{cf}^2 + \beta_{12} NOC_{cf}^3 + \varepsilon_{cf}$$

Where COM = (0, 1) is equal to 1 if control *c* at firm *f* reported compliance, equal to 0 otherwise. The included variables are the continuous year, dummies for risk class, control type, period, monitoring classification and number of items checked during a control, and the random error term ε_{cf}. For descriptions of the explanatory variables, see table 4.5.

4.4.2. Model 2: Consecutive violations

To investigate how firms respond in a dynamic setting, this dependent variable is created to investigate consecutive violations. The initial intention was to detect whether or not firms take action to correct deviations that have been registered by the NEA. Firms with consecutive violations are defined as firms where two or more controls in a row to detect a violation. The logit model for consecutive violations is specified in (2).

$$(2)\ CON_{cf} = \beta_0 + \beta_1 YR_{cf} + \beta_2 IN_{cf} + \beta_3 RC_{cf}^2 + \beta_4 RC_{cf}^3 + \beta_5 RC_{cf}^4 + \beta_6 CT_{cf}^2 + \beta_7 CT_{cf}^3 + \beta_8 CT_{cf}^4 + \beta_9 PER_c + \beta_{10} MON_{cf} + \beta_{11} NOC_{cf}^2 + \beta_{12} NOC_{cf}^3 + \varepsilon_{cf}$$

Where CON = (0, 1) is equal to 1 if control *c* at firm *f* is the second or more in a row to report violations, equal to 0 otherwise. The included variables are the continuous year, dummies for risk class, control type, period, monitoring classification and number of items checked during a control, and the random error term ε_{cf}. For descriptions of the explanatory variables, see table 4.5.

4.4.3. Model 3: Severe deviations

Severe deviations are violations that by NEA are deemed as particularly serious breaches of the pollution permit, and entail increased monitoring, larger fines and the risk of being reported to the police for investigation. The logit model for severe deviations is specified in (3):

$$(3)\ SEV_{cf} = \beta_0 + \beta_1 YR_{cf} + \beta_2 IN_{cf} + \beta_3 RC_{cf}^2 + \beta_4 RC_{cf}^3 + \beta_5 RC_{cf}^4 + \beta_6 CT_{cf}^2 + \beta_7 CT_{cf}^3 + \beta_8 CT_{cf}^4 + \beta_9 PER_c + \beta_{10} MON_{cf} + \beta_{11} NOC_{cf}^2 + \beta_{12} NOC_{cf}^3 + \varepsilon_{cf}$$

Where SEV = (0, 1) is equal to 1 if control *c* at firm *f* detects severe deviations, equal to 0 otherwise. The included variables are the continuous year, dummies for risk class, control type, period, monitoring classification and number of items checked during a control, and the random error term ε_{cf}. For descriptions of the explanatory variables, see table 4.5.

5. RESULTS AND DISCUSSION

In order to address the hypotheses stated in *Section 1.1*, we will be looking at the three models with compliance, consecutive violations and severity as the dependent variable. In Table 5.1 below, the expected signs of the variables are presented, according to the postulated hypotheses.

Table 5.1 Expected signs

Hypotheses	**Variable**	**Model 1: Compliance**	**Model 2: Consecutive violations**	**Model 3: Severe deviations**
Firm characteristics		**Expected sign**	**Expected sign**	**Expected sign**
H1a: Oil and gas less compliant	Land-based industry	+		
H1b: More consecutive violations in oil and gas	Land-based industry		-	
H1c: More serious breaches in oil and gas	Land-based industry			-
H2a: Less compliance in risk class 1	Risk class 2 – 4	+		
H2b: Less repeated offenders in low-risk firms	Risk class 3 & 4		-	
H2c: Less severe deviations in low-risk firms	Risk class 3 & 4			-
Monitoring methods				
H3a: System revisions find more violations	System revisions	-		
H3b: Emergency controls find more violations	Emergency controls	-		
H3c: Other controls find more compliance	Other controls	+		
H3d: More items controlled find more violations	6 – 10, 10+	-		
H3e: Particular monitoring leads to compliance	Normal monitoring	-		
Time period				
H4a: Compliance increase as technology improves	Year	+		
H4b: Compliance decrease after the financial crisis	2006 – 2011	-		
H4c: More repeated offenders after 2005	2006 – 2011		+	

Note: For a detailed description of risk classes, see Table 4.1.

Before we proceed with the regression result, it will be important to establish whether or not there is a strong correlation between the variables in the data. As seen from the correlation matrix in *Appendix 1*, there is, not surprisingly, a high correlation between the variables year and period. This will not present any problems for our analysis, as these will not be included in the same regression.

Several logit model estimations will be tested for each model. These are denoted A through H, where A - D tests the complete data set, while E and F excludes all observations for oil and gas, resulting in a sample for 'land-based industry'.

The last two model estimations, G and H, are solely tested on the restricted sample 'latest control'. In this sample, only the latest control for each firm is included, such that the data set consists of one observations per firm. We must keep in mind that the data selection for these two estimations might give a skewed representation of actual compliance since the outcome of the last observed control can give a misleading representation of the series of controls.

5.1. Model 1: Compliance

The first model investigates factors associated with the probability of being in compliance with pollution permits. The regression analysis results are reported for several logit model estimations for Model 1, denoted 1A through 1H.

As seen in Table 5.2, we find that most included variables are significant at the 95% level or higher in the model estimations for the complete data set (1A – 1D) and the data selection from land-based industry (1E – 1F). The year variable is the exception, which is only significant in 1E. Additionally, we confirm the assumed weaknesses in the results from the model estimations 'latest control', as discussed in *Section 4.1.1 Weakness of data*, with only two significant variables in each estimation. Here, in 1G and 1H we also note high standard errors for the significant variables risk class 3 and system revisions. This leads us to believe that we can place little reliability on the results of this estimated model and that we cannot draw any conclusions based on this sample.

Table 5.2 Regression results for Model 1: Compliance

	Complete data set				Land-based industry		Latest control (One obs. per firm)	
Explanatory variables	**1A**	**1B**	**1C**	**1D**	**1E**	**1F**	**1G**	**1H**
Industry								
Land-based industry	-0.821***		-0.886***				-0.686	-0.702
	(0.239)		(0.240)				(0.632)	(0.634)
Risk class								
Risk class 2	-0.675***	-0.793***	-0.644***	-0.768***	-0.578***	-0.547***	-0.748	-0.754
	(0.165)	(0.150)	(0.165)	(0.160)	(0.173)	(0.174)	(0.459)	(0.459)
Risk class 3	-1.338***	-1.457***	-1.299***	-1.422***	-1.266***	-1.246***	-1.241***	-1.283***
	(0.367)	(0.172)	(0.175)	(0.171)	(0.184)	(0.183)	(0.442)	(0.440)
Risk class 4	-1.335***	-1.456***	-1.311***	-1.432***	-1.338***	-1.360***	-0.901	-1.019
	(0.259)	(0.355)	(0.356)	(0.353)	(0.362)	(0.362)	(0.564)	(0.569)
Control type								
System revisions	-1.258***	-1.118***	-1.250***	-1.099***	-1.345***	-1.340***	-2.091***	-2.108***
	(0.181)	(0.171)	(0.181)	(0.170)	(0.216)	(0.216)	(0.538)	(0.538)
Emergency inspections	-1.951***	-1.947***	-2.012***	-2.007***	-1.755***	-1.852***	-1.309	-1.465
	(0.367)	(0.366)	(0.367)	(0.366)	(0.393)	(0.391)	(1.093)	(1.098)
Other controls	1.538***	1.504***	1.464***	1.427***	1.142***	0.994***	1.032	1.061
	(0.258)	(0.259)	(0.260)	(0.261)	(0.280)	(0.285)	(0.752)	(0.755)
Year	-0.237	-0.016			-0.076***		-0.023	
	(0.015)	(0.014)			(0.018)		(0.049)	
Periods								
2006 – 2011			-0.467**	-0.397**		-0.976***		-0.615
			(0.134)	(0.131)		(0.166)		(0.416)
Monitoring classification								
Normal					2.125***	2.106***		
					(0.477)	(0.476)		
Items controlled								
5 – 10					-0.582***	-0.657***		
					(0.176)	(0.176)		
10+					-0.906***	-1.056**		
					(0.225)	(0.220)		
N	1602	1602	1602	1602	1487	1487	447	447
Log likelihood	-777.66	-783.45	-772.83	-779.50	-669.71	-660.67	-192.41	-191.48
LR chi2 (7)	222.69	169.01	230.34	217.01	273.97	185.77	25.94	27.78
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
Pseudo R2	0.123	0.095	0.130	0.122	0.170	0.115	0.063	0.068

* Significant at 10%, ** significant at 5%, *** significant at 1%. Standard errors are reported in parenthesis.
Dependent variable: 1 = control found compliance, 0 = control detected violations.
Reference categories: Oil and gas sector, risk class 1, inspections, 1997 - 2005, particular priority, 0 - 5 items.
See table 5.1. for more details on the variables.

5.1.1. Hypotheses on firm characteristics

Industry

Hypothesis *H1a: Oil and gas less compliant* states that firms in the land-based industry are more likely to be in compliance with pollution permits than those in the oil and gas sector. According to the regression results presented in Table 5.2, we have found evidence to refute this hypothesis. Although the coefficients for the dummy variable industry are not statistically significant in 1G and 1H, they are statistically significant at the 99% level in 1A and 1C. Here, the coefficient for land-based industry has a negative sign in both estimations. This indicates a reduced probability of complying to the pollution permit for firms in the land-based industry, as opposed to those in oil and gas. Although the coefficient for land-based industry is not statistically significant in 'latest control', we consider the results from the complete data set to be more reliable due to the previously discussed issues with model 1G and 1H. Thus, we base our rejection of *H1a* on the findings from the complete data set.

A possible explanation to why there is a greater probability of compliance in the oil and gas sector, as opposed to what was postulated in *H1a*, may be the perceived risk of detection. All firms in the offshore sector are placed in risk class 1. NEA's monitoring schedule suggests that these firms are subject to greater control-frequency with one inspection every year, and system revisions every third year. This leads us to think that compliance is greater by regulated agents that think there is a stronger likelihood of violations being detected. The notion that firms within the oil and gas sector have a greater probability of complying than expected can be supported by previous studies (see Burby & Paterson, 1993; Gray & Scholz, 1991). Here, the authors have done empirical studies on enforcement of environmental regulations and state that the expected risk of being caught in non-compliance is more important in shaping lawful behavior than the likelihood and severity of sanctions. These claims can suggest that firms in oil and gas comply more because there is an increased risk of being caught due to greater thoroughness of controls and an increased monitoring frequency.

To further support our findings, Cohen (1987) found in his study on oil spills in the US that even if the penalty were to remain unchanged, the principal, in his case the Coast Guard, may be able to achieve more compliance by shifting enforcement efforts into more detailed port patrols, or by directly monitoring the oil transfers at platforms. Cohen's results may give some support to our finding that firms in oil and gas are more likely to comply because they are placed in a risk class where they are under more scrutiny from NEA.

Another feasible argument that supports the rejection of our hypothesis, *H1a: Oil and gas less compliant* is the financial capacity and priorities of the firms. Here, one can assume that firms in the offshore industry have a better ability to comply with regulations because of available resources. Although we lack data on firm size, and this could be an important factor that affects compliance, we can assume that oil and gas is a capital-intensive sector. Hence, the assumption can be made that firms in this sector has a greater capacity to comply since firms of their size are likely to have a compliance and risk management department, indicating that internal risk measures may be a part of every-day operations. This also entail that they are more likely to have more detailed knowledge of the pollution control act versus firms in land-based industry, which may include small "mom and pop" firms that might have one employee in charge of health, safety and environment (HSE). Because the risk of being caught is higher, and the potential economic consequences of being in non-compliance could be especially high, firms in oil and gas have a an incentive to act with some risk-aversiveness. Here, a breach with the law, or even suspicion of a leak or spill, could lead to a halt in the production process, which could be of an immense effect on the profit margin. The oil and gas sector also face larger economic consequences as fine levels and cost of inspections are higher for firms in risk class 1. Combined with a higher frequency of controls if caught with violations, the cost of the inspection is another economic consequence to consider. Consequently, offshore plants in risk class 1 face higher possible sanctions in case of criminal prosecution.

The consequences of being in non-compliance, or even a potential oil spill, is not limited to economic and legal ramifications, it could also entail a drastic loss of reputation. In their article, Roberts and Dowling (2002) state that firms that are performing well financially have a much greater chance at sustaining the economic performance in the long run if they maintain a good reputation. Combining the oil and gas sector's already tainted reputation with the higher associated risk of accidents that can cause detrimental damage to the environment, one can assume that the loss of reputation would be greater for oil and gas firms, leading them adopt more precautionary measures to limit the risk of bad publicity.

As previously discussed, we have not been able to gather information on the marginal abatement costs of the controlled firms. This has to be considered a crucial limitation in our data, as we are not able to distinguish at what level the expected penalty surpasses the abatement costs. Although we must reject H1a, it seems evident that the oil and gas sector act with some risk-precaution, and this might explain why their compliance is higher than what we expected.

Risk class

We postulate in *H2a: Less compliance in risk class 1* that firms in the lower risk classes are more likely to be in compliance than firms in risk class 1. Our results show that firm-assigned risk classes for compliance are substantively and statistically noteworthy at the 95% level or higher for all models in the complete data set, as well as the data from land-based industry exclusively. Risk class 3 is also significant in 1G and 1H. The estimated coefficients for the effect of risk class indicate that there is a negative relationship for the dummy variables risk class 2, 3 and 4. Here, it is evident that all firms classified with smaller threat of pollution are less likely to be in compliance than the strictest classification and reference group, risk class 1. This refutes our hypothesis *H2a,* that the firms that pose the greatest environmental threat has a higher tendency to violate the designated pollution permits, compared to lower-risk firms.

There might be many reasons for these findings, which corresponds with the rejection of *H1a: Oil and gas less compliant*. Again, it might be explained by previous research, here Bye and Klemetsen (2014) suggests that firms in high risk classes are more sensitive to threats of penalties and fines, and thus have a greater incentive to comply. In similarity with research by Telle and Nyborg (2006), we have also found the enforcement system for minor violations to be lax, with fine warnings, in the form of a letter, as the standard response. The sensitivity to threats of sanctions might contribute to the explanation to why our results find that firms in high-risk classes have a lower tendency to violate regulations.

According to Becker's model (1968) one would assume that firms speculate in breaching the law if the expected penalty is lower than the compliance cost, and breaking the law because paying the fines will be beneficial compared to investing to comply. We do not intend to claim that low-risk firms speculate in breaking the law, and we find no sound evidence to support Becker's notion as we have no data on individual compliance expenditure. However, an argument can be made that the variable for risk class include a portion of a firm's expected penalty, as both monitoring frequency and economic fines are decided in accordance to risk class. Although the costs of inspections are considered marginally low for firms in the upper risk classes, the perceived risk of formal accusations and prosecution is present. This might indicate that the marginal damage to high-risk firms is greater even when it is not financially explicit, but comes in the form of a damaged reputation if violations were made public and the expected threat of harsh criminal penalties.

As for the industry variable, we could have performed a more detailed analysis had information on abatement costs been available. It would also have been interesting to compare the expected penalty to the revenue of the different firms, as the implications of a set fine differ for firms with different incomes and thereby ability to pay.

According to the results for model estimations 1A through 1F, a rejection of *H2a* indicates that risk class 3 and 4 have a negative impact on firms' compliance to pollution permits compared to firms in risk class 1. According to NEA's baseline for monitoring frequency, presented in Table 2.3, firms in risk class 3 are scheduled for an inspection every second or third year, and are not scheduled for system revisions, while firms in risk class 4 are only scheduled for inspections when needed. As the low-risk firms are subject to the least frequent monitoring, this contradicts the notion of Harrington paradox that there should still be an abundance of compliance among these firms.

5.1.2. Hypotheses on monitoring methods

Control type

According to the regression results, control type is a relevant predictor in explaining firms' compliance with permits. The dummy variable for system revisions is significant at the 99%

level with a negative sign for all model estimations, including 1G and 1H; 'latest control'. This corresponds with our expectation in *H3a: System revisions find more violations*, thus we cannot reject our hypothesis that system revisions has a greater impact on non-compliance than the reference group, inspections. System revisions are longer-lasting controls that monitor the environmental management system as well as the internal control system at the controlled entity. Further, the firm will be inspected in greater detail, indicating that the thoroughness of the control will leave little leeway to the firm. Thus, it will be more difficult for the firm to hide its actions or engage in a "manipulative behavior" during system revisions. According to NEA's pre-determined plan for monitoring frequency, presented in Table 2.3, system revisions are only performed at firms placed in the two highest risk classes.

After refuting *H2a: Less compliance in risk class 1*, where firms in risk class 1 proved to have a positive impact on compliance because the expected risk of detection is larger, we see a similar indication for *H3a*. Because system revisions are more likely to uncover violations than inspections, the higher level of compliance in risk class 1 can be interpreted as a result of the frequent use of system revisions when controlling firms in this risk class. This monitoring method induces firms to comply because there is greater transparency concerning their behavior.

Further, after failing to reject *H3a: System revisions find more violations*, and correspondingly refuting *H2a,* our findings can be supported by previous studies. According to Heyes, more thorough inspections provide firms with incentives to switch to more transparent technologies, which in return can lead to a greater detection-rate and avoidance of type II errors. Entire internal systems and procedures are difficult to manipulate with the intent to keep information from the controlling authorities, and decreases the chance of wrongful control results. Here, Heyes claims that better thoroughness will lead to a higher detection rate, implying that it will be more difficult for firms to conceal violations during a more extensive control. (Heyes, 1994; 1998).

We find that low risk classes, which are mainly monitored through inspections, have a higher tendency to violate the permit. Thereby, we can argue that thoroughness of controls is more important than monitoring frequency in detecting violations. Here, Heyes (1994) confirm our belief that a sole increase in frequency of controls might, in fact, lead firms to move in the other direction, away from transparency, causing worse environmental performance over time. Consequently, these shorter but more frequent inspections, will be more superficial by nature and can make it possible for firms to conceal their actions.

Further, system revisions are always announced. Inspections are less extensive, and according to Orvik at NEA (2015), around 40% of these are unannounced. It would have been interesting to investigate the difference in control results between the announced and unannounced inspections. We would postulate that the unannounced inspections uncovered more violations by catching firms off-guard, but unfortunately, there is no data available on the distinction, making an analysis of this impossible.

We would also like to examine the less frequently used monitoring methods, namely 'emergency inspections' and 'other controls'. These are both significant at the 99% level in six of the eight model estimations. However, the variables are not significant in the two model estimations 1G and 1H. As previously discussed, this issue is of little importance due to the unrepresentative and random selection of data included in 'latest control'. The coefficient for 'emergency inspections' has a negative sign in all model estimations 1A - 1F, indicating that emergency inspections decreases the likelihood of compliance, meaning we cannot reject our hypothesis. This is not very surprising, as the controls are performed in cases of accidents like oil spills or on the basis of reported suspicion, such as unlawful dumping of hazardous waste.

When it comes to the category 'other controls', such as letter controls, random sample tests, source-specific emission measurements, the coefficients in model estimations 1D and 1E has a positive effect. Our postulation *H3c: Other controls find more compliance* states that controls that fall in this category detect violations at a lower rate than inspections, and cannot be rejected. These controls are performed less often than inspections and system revisions, and are more superficial by nature. According to the NEA the intent behind these controls is not necessarily to uncover violations, but to execute some authoritative presence, create dialog and a basis for a good relationship and collaboration. (NEA; Orvik, 2015). One could assume that this regulatory presence might function as a reminder to firms that there is a chance of unannounced inspections. In a study performed by Kjetil Telle at SSB in collaboration with NEA, they found that issued letter controls in fact contributed to improve the level of compliance overall in product control, and that firms respond to these letters by correcting violations (NEA; Orvik, 2015). Although this study was performed in a different sector, it is reasonable to assume that the effect might be similar in land-based industry and the oil and gas sector.

Number of items inspected

Another factor we have included when examining the effect of NEA's monitoring methods, is the number of items inspected during a control. In accordance with *H3a: System revisions find more violations*, we postulate in *H3d: More items controlled find more violations* that more than 5 items is likely to have a negative impact on compliance. This hypothesis is tested in 1E and 1F, as the data for this variable is only available for land-based industry. Due to this limitation in the data, the results may not be representable for other industries.

The dummy variables for 5 - 10 items and 10+ items controlled are both significant in 1E and 1F at the 95% level or higher. All four coefficients are negative, meaning that we cannot reject *H3d* that controls with more than 5 items have negative impact on compliance compared to controls that check 1-5 items. Again, this is in agreement with our findings concerning *H3a* that system revisions seem to uncover non-compliance at a higher rate than inspections, and that the detection rate increases with the thoroughness of the monitoring method. Further, an argument can be made that the more items controlled can contribute to decrease the issue of moral hazard, as NEA through these controls gain more extensive information about the controlled firm and their activities. The issue of asymmetric information seems to decrease as both number of items inspected and thoroughness increase, as seen in both *H3a* and *H3d*.

Monitoring classification

Of further interest is NEA's monitoring methods that include previous behavior. Of particular interest is the firms whose prior control revealed deviations such that the recommendation resulted in "control more frequently", denoted as particular priority. Information on monitoring categorization is only available for the sample 'land-based industry' and will thereby be tested in 1E and 1F. The dummy variable for normal monitoring is significant with a positive sign at the 99% in both model estimations, meaning that controls of firms under normal monitoring are more likely to positively affect compliance, than the reference category particular priority. According to Harrington (1988) and Scholz (1984), the regulator may increase overall compliance rates by targeting those who have been repeated offenders. On the basis of these theoretical models, we postulate in *H3e: Particular monitoring leads to compliance* that firms that are monitored under the classification particular priority are more likely to comply with the permits in the succeeding control. According to the model estimations 1E and 1F, the hypothesis has to be rejected.

The rejection of *H3e* can be explained by the fact that firms under 'particular monitoring' are subject to more frequent and thorough controls than firms under 'normal monitoring', hence violations are detected more often. However, firms that are placed in the category for monitoring of particular priority, are not informed of this. This present an issue of asymmetric information, where the regulator intentionally withholds information from the controlled firm. In accordance with principal-agent theory, it can be assumed that firms would adjust their behavior if they were made aware of the increased monitoring priority.

Based on our postulation, and according to Harrington (1988) and Scholz's (1984) claims that compliance increases as previous offenders are especially monitored, our results are somewhat surprising. Moreover, there seems to be a dichotomous relationship between the level of enforcement and rate of compliance. This is supported by Deily and Gray in their study of compliance with air pollution regulations at steel plants in the U.S, and the enforcement of these. The authors claim that higher level of enforcement encourage higher level of compliance, while higher levels of compliance will again lead to lower levels of monitoring by the NEA (Gray & Deily, 1996). This classification is a perfect example of the typical causality dilemma of "the chicken or the egg". Here, it is difficult to determine if the observed effect is based on firms being placed in the category due to non-compliance, or being in non-compliance because they are placed under monitoring of particular priority. Hence, contributing toward a continuous cycle of adjustments in enforcement level, making the task of deciding monitoring intensity difficult.

5.1.3. Hypotheses on year and period

When analyzing the effect of year and period on compliance, we must remember that we are working with unbalanced panel data. Here, the NEA consider its monitoring schedule based on potential risk and level of environmental damage when deciding how often to control firms. In terms of the data sample 'latest control', the latest observation for each firm will be registered in different years, such that the control might be performed under varying circumstances concerning economic environment, monitoring methods and regulatory demands. Thereby, the results from these estimations should be interpreted with care.

Due to the high correlation between year and period, the two variables are not included in the same regression, but rather tested in four model estimations each. Year is significant at the 99% level in 1E that tests data from land-based industry, but not significant in any of the other model estimations, indicating that the variable may be significant only under certain conditions. Our expectation in *H4a: Compliance increase as technology improves* was that the increased environmental pressure, combined with a decrease in marginal abatement cost over time due to better technology, would lead to more compliance in later years. The regression results refute this hypothesis, as the variable year has a negative effect on compliance. However, we must keep in mind that the variable is not significant in the model estimations 1A, 1B and 1G, and the reliability of this result is questionable.

In *H4b: Compliance decrease after financial crisis,* we postulate that the period after 2005 has a negative effect on compliance compared to the period 1997 - 2005. Although we assumed more compliance as technology improves, presumably leading to a decrease in marginal abatement costs, as most economic literature suggests, it is plausible to assume that fluctuations in the economy will affect firms ability to comply. Consequently, it may seem as though *H4a: Compliance increase as technology improves* and *H4b: Compliance decrease after financial crisis* are somewhat contradictory. Here, we distinguish between the aggregate compliance effect over a period of 14 years and the short-term effect of the period after 2005. Ideally, we would have data that span over a longer time period, which could potentially have illustrated the effect in a better manner, and led to a different outcome of hypothesis *H4a*. This is supported by what we observe in Figure 4.1, where the percentage of compliance in the period 1997 - 2011 is displayed. Here, we see some variations in the percentage of compliance from 1997 to 2005, but the underlying trend is an increase in compliance in this period.

Based on the descriptive statistics from the raw data in Figure 4.1, we hypothesized that the period after 2005 may have a negative effect on compliance, as a result of an early onset of the financial crisis of 2008. The variable period is significant in three of the four model estimations at the 95% level or higher with a negative sign. This means that we cannot reject our hypothesis H5b; that firms are more likely to be in non-compliance in the period after the early onset of the financial crisis, by our definition 2006 - 2011. Thus, this indicates that the period after 2005 have had a negative impact on compliance. According to Becker (1968), the expected penalty for non-compliance is considered equal to other business expenses faced by the firm. Here, one could argue that firms would comply in order to avoid the penalty expense. However, when looking at a profit-maximizing firm, environmental efforts may be at the bottom of the list of priorities in periods of economic downturns.

Further supporting our finding, Laffont (1995) examines the potential issues of moral hazard when a firm is faced with direct environmental regulations. He argues that regulatory demands, combined with the competition from other firms, induce a greater focus on cost-minimization, and that this might lead to a "trade-off" where the agent is forced to take more risk. In times of economic downturns, one could argue that the pressure to retain customers, and keep on-time delivery according to contract, is especially great since the consequence of losing business is particularly large and can potentially lead to bankruptcy. The two possible outcomes in such instances might be to violate the permit, in order to reach production target, or possibly face an increased marginal abatement cost since technology investments probably will not be prioritized when costs are minimized (Laffont, 1995). Although we see a negative effect of the period after 2005 on compliance, we can only suggest that the financial crisis was the sole reason for this. It is worth noting though, that there are many other factors that could have led to the decrease in compliance during this period, such as changes in monitoring methods, regulatory environment or increased funding to the NEA.

To summarize the findings in Model 1, most variables were statistically significant at the 95% level or higher, for all models. We can see from Table 5.3 that three of the hypotheses were rejected. Additionally, we keep in mind that the results from *H4a* regarding year only found weak evidence to reject.

Table 5.3 Findings of expected signs for Model 1: Compliance

Hypotheses	Variable	Expected sign	Reject?
Firm characteristics			
H1a: Oil and gas less compliant	Land-based industry	+	Yes
H2a: Less compliance in risk class 1	Risk class 2 – 4	+	Yes
Monitoring methods			
H3a: System revisions find more violations	System revisions	-	No
H3b: Emergency controls find more violations	Emergency controls	-	No
H3c: Other controls find more compliance	Other controls	+	No
H3d: More items controlled find more violations	6 – 10, 10+	-	No
H3e: Particular monitoring leads to compliance	Normal monitoring	-	Yes
Time period			
H4a: Compliance increase as technology improves	Year	+	?
H4b: Compliance decrease after the financial crisis	2006 – 2011	-	No

For a detailed description of risk classes, see Table 4.1.
Yes denotes that the null hypothesis is rejected. No denotes that the null hypothesis cannot be rejected.

5.2. Model 2: Consecutive violations

So far, we have focused on compliance as the dependent outcome. In order to eliminate the chance of one-time offenses, we are interested in examining those firms who repeatedly are caught violating the permit, and consequently which factors contribute to notorious breaches of the law. We therefore proceed by analyzing the probability of having consecutive violations in subsequent controls. Here, we acknowledge the chance that the following control actually examines different criteria within the permit than the preceding, and that the original violations have indeed been corrected. This indicates that a firm caught with deviations to the permit on internal auditing routines in one control, can in the next control be caught with incorrect treatment of hazardous waste. These differences are hard to separate since NEA might perform “themed” controls, where there is one area of focus across all plants that are monitored that year, and these might differ each year.

While taking this into account, we will investigate the dependent variable consecutive, where a firm is considered to have consecutive violations if two or more controls in a row reveal deviations. Table 5.4 reports the regression results for the logit model, using the same set of variables as in Model 1. Each separate model estimation is denoted 2A through 2H, where 2A - 2D tests the complete data set, 2E and 2F test the data set for ‘land-based industry’ and 2G and 2H tests the sample ‘latest control’.

In the model estimations for consecutive violations displayed in Table 5.4, control type appears to be an important factor in predicting consecutive violations, while risk class seems to have less predictive power. We again confirm the assumed weaknesses in the results from model estimations 2G and 2H, testing the data sample ‘latest control’. In 2G, year and industry are the only significant variables, and industry is only significant at the 90% level with a rather high standard error. In 2H, industry is significant at the 90% level, again with a high standard error, and period is significant at the 99% level. We suspect that the year and period variable pick up effects from other factors that are not included in the model, and thereby is weighted too heavily.

Table 5.4 Regression results for Model 2: Consecutive violations

	Complete data set				Land-based industry		Latest control (One obs. per firm)	
Explanatory variables	**2A**	**2B**	**2C**	**2D**	**2E**	**2F**	**2G**	**2H**
Industry								
Land-based industry	1.287*** (0.251)		1.233*** (0.250)				0.938* (0.502)	0.956* (0.501)
Risk class								
Risk class 2	0.916 (0.142)	0.289** (0.137)	0.133 (0.140)	0.317** (0.136)	0.016 (0.146)	0.076 (0.144)	0.143 (0.350)	0.111 (0.349)
Risk class 3	-0.171 (0.146)	0.026 (0.142)	-0.106 (0.146)	0.076 (0.171)	-0.262* (0.150)	-0.165 (0.148)	-0.248 (0.343)	-0.251 (0.342)
Risk class 4	-0.659** (0.293)	-0.461 (0.290)	-0.559* (0.290)	-0.381 (0.288)	-0.733** (0.299)	-0.584** (0.294)	-0.507 (0.468)	-0.439 (0.471)
Control type								
System revisions	0.348** (0.187)	0.220 (0.134)	0.365*** (0.137)	0.241* (0.133)	0.349** (0.148)	0.398*** (0.147)	0.201 (0.274)	0.242 (0.276)
Emergency inspections	-0.797*** (0.215)	0.813*** (0.213)	0.744*** (0.213)	0.762*** (0.212)	0.727*** (0.241)	0.640*** (0.238)	0.125 (0.652)	0.235 (0.666)
Other controls	-1.019*** (0.306)	-0.951*** (0.305)	-1.018*** (0.316)	-0.959*** (0.306)	-0.840*** (0.323)	-0.868*** (0.324)	-0.683 (0.834)	-0.753 (0.836)
Year	0.084*** (0.012)	0.074*** (0.012)			0.121*** (0.015)		0.105** (0.041)	
Periods								
2006 – 2011			0.629*** (0.110)	0.548*** (0.108)		0.896*** (0.133)		1.372*** (0.417)
Monitoring classification								
Normal					-0.527*** (0.190)	-0.505*** (0.188)		
Items controlled								
5 – 10					0.269** (0.136)	0.210 (0.135)		
10+					0.497*** (0.175)	0.365** (0.174)		
N	1602	1602	1602	1602	1487	1487	447	447
Log likelihood	-1019.87	-1034.87	-1027.21	-1041.04	-939.97	-951.06	-298.76	-295.78
LR chi2 (7)	113.47	83.47	98.78	71.14	134.01	111.82	18.40	24.36
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.002
Pseudo R2	0.053	0.039	0.046	0.033	0.067	0.056	0.030	0.040

* Significant at 10%, ** significant at 5%, *** significant at 1%. Standard errors are reported in parenthesis.
Dependent variable: 1 = consecutive violations, 0 = no consecutive violations.
Reference categories: Oil and gas sector, risk class 1, inspections, 1997 - 2005, particular priority, 0 - 5 items.
See table 5.1. for more details on the variables.

5.2.1. Hypotheses on firm characteristics

Industry

The rejection of *H1a: Oil and gas less compliant,* leads us to question the viability of *H1b: More consecutive violations in oil and gas*. Here, we postulate that firms in oil and gas have a negative effect on consecutive violations compared to firms in land-based industry. Hypotheses *H1b* was initially based on the notion that firms in the oil and gas sector would have more serious violations, that would take longer to correct between the controls. From Table 5.2 we see that industry is significant at the 95% level or higher in 2A and 2Cat the 90% level in model estimations 2H and 2G. The dummy coefficient for land-based industry has a positive effect on consecutive violations compared to oil and gas. This is opposite of our expectation, and we must therefore reject the hypothesis *H1b: More consecutive violations in oil and gas*.

There might be many reasons for the rejection of *H1b*, such as the large differences in both firm size and type of operations within the land-based industry. Compared to oil and gas we assume that there is a presence of smaller sized firms within land-based industry. For these smaller firms, we suspect that the violations may be caused by a lack of resources, limited knowledge about the regulatory framework, inability to comply or any combination of these. This is supported by a study performed by Winter and May (2001) on Danish farmers' compliance to agro-environmental direct regulations. Here, the authors find that the ability to comply, especially in terms of awareness of rules, plays a critical role in determining if farmers have deviations.

Becker (1968), on the other hand, makes the assumption that firms will speculate in breaking the law if it is considered profitable in the long term. According to Walle (2003), NEA reacts with strict sanctions if there is suspicion that the firm speculates in breaking the law. In this case, the penalty will reflect previous behavior, such that firms with recurring non-compliance will receive higher penalties than firms that have a history of compliance. It can be argued that NEA sends a signal to the firms with these stricter penalties; although the monitoring and enforcement of compliance to a large degree is based on trust, firms will lose this trust if deliberate violations are suspected. However, we have no evidence in supporting the claim that firms will successively break the law whenever they find it profitable.

Risk Class

In *H2b: Less repeated offenders in low-risk firms*, we propose that low-risk firms, in risk class 3 and 4, have a negative effect on consecutive violations compared to firms in risk class 1. As risk class 3 is only significant in 2E at the 90% level, this is a weak statistical result, and we cannot assume the variable to be explained with accuracy. Risk class 4, on the other hand, is significant in four of the eight model estimations at the 90% level or higher, and the accuracy of the results regarding risk class 4 is somewhat higher. In model estimation 2E, risk class 3 has a negative coefficient. Similarly, risk class 4 has a negative sign in model estimations 2A, 2C, 2E and 2F. For risk class 3, our results are inconclusive. For risk class 4, on the other hand, we cannot reject hypothesis *H2b* as we find that these firms are less likely to have consecutive violations compared to firms in the strictest risk class. After rejecting *H2a: Less compliance in risk class 1,* this result is somewhat surprising. However, we assume that this might be caused by the ability of firms in risk class 4 to correct minor violations between controls.

Nadeau (1997) performed a study of EPA's effectiveness in reducing the duration of plant-level non-compliance. In this study, Nadeau treated non-compliance as something that occurs over a period of time, rather than a momentary occurrence. Results of the study showed that increases in monitoring and enforcement activity lead to reductions of the expected violation time. Our findings, on the other hand, indicate that firms faced with higher levels of monitoring and enforcement, such as risk class 1, have a larger share of consecutive violations. Our findings show opposite results of what Nadeau suggests in his studies. However, we keep in mind that risk class 1 is subject to a substantially higher control frequency and thoroughness compared to lower risk classes. Thus, we have to be aware that there may be undetected violations in the lower risk classes. There are also limitations in our data, and the validity of the results are questionable as there are several model estimations where the dummy variables for risk class 3 and 4 are not significant.

5.2.2. Hypotheses on monitoring methods

We propose in hypothesis *H4c: More repeated offenders after 2005* that controls performed in the period 2006 - 2011 will have a positive effect on consecutive violations compared to those before this period. To put it more simply, we assumed that the financial crisis led to more repeated violations. Our postulation is based on the notion that firms started to experience the early onset of the financial crisis already two years prior to the market hit, around 2006.

The dummy variable for the period 2006 - 2011 is significant at the 99% level in model estimations 2C, 2D, 2F and 2H, indicating that controls performed after 2005 are more likely to report consecutive violations. Thus, we cannot reject hypothesis *H4c*. We expect that this is due to the limited resources firms' experienced during the financial crisis, and that the means to correct already existing violations were limited. Indications of this can also be found within the literature. Stafford (2002) states that correction of violations takes time, especially if the installment of new technology is required. Additionally, Laffont's studies (1995) indicate that environmental regulatory policies can induce a greater focus on cost-minimization, and that the trade-off created can lead firms to take more risk. Consequently, costly investments in time-consuming processes that are not relevant to the production performance of the firm are not likely to be prioritized during times where firms experience particular financial strain.

Table 5.5 Findings of expected signs for Model 2: Consecutive violations

Hypotheses	Variable	Expected sign	Reject?
Firm characteristics			
H1b: More consecutive violations in oil and gas	Land-based industry	-	Yes
H2b: Less repeated offenders in low-risk firms	Risk class 3 & 4	-	?
Time period			
H4c: More repeated offenders after 2005	2006 – 2011	+	No

For a detailed description of risk classes, see Table 4.1.
Yes denotes that the null hypothesis is rejected. No denotes that the null hypothesis cannot be rejected.

To summarize the findings in Model 2, we saw significant effects of industry period. The hypothesis for industry was rejected, while we could not reject our postulation regarding period. Results regarding risk class were inconclusive. We acknowledge that a hypothesis on control type should have been postulated, as this variable proved to be a significant predictor.

5.3. Model 3: Severe deviations

After having examined the results from Model 1 and 2, with compliance and consecutive violations as the dependent outcome, we are now interested in examining the factors that lead to the most serious offenses. Severity of the violations is interesting because the economic consequences, as well as risk of prosecution and loss of reputation, is much greater if firms are caught with severe deviations. Each separate model estimation is denoted 3A through 3H, where 3A - 3D tests the complete data set. 3E and 3F tests the data set for 'land-based industry', while 3G and 3H tests the restricted sample 'latest control'.

Before we look at the hypotheses for firm characteristics, we see from Table 5.6 that a majority of the coefficients are in fact not statistically significant. This gives us an indication that the model is unreliable. In addition, the variables 'other controls' and 'period' are dropped due to homogeneity in the data. Here, no severe deviations were detected in controls before 2006, nor have any 'other control' ever revealed a severe deviation. We also note the issue of high standard errors for most model estimations, particularly high in 3G and 3H. Consequently, we must treat Model 3 with some caution, and acknowledge that the results are empirically weak.

Lastly, we note that NEA's monitoring method should have been included as a factor in our hypotheses, as 'emergency inspections' is the only variable to be significant in all model estimations, although with a rather high standard error. The significance of 'emergency inspections' in predicting severe deviations is not surprising, as the nature of these controls include monitoring when particular suspicion is reported or in the case of large accidents, such as an oil spill.

Table 5.6 Regression results for Model 3: Severe deviations

	Complete data set				Land-based industry		Latest control (One obs. per firm)	
Explanatory variables	**3A**	**3B**	**3C**	**3D**	**3E**	**3F**	**3G**	**3H**
Industry								
Land-based industry	0.452 (0.700)		0.423 (0.696)				-0.432 (1.006)	-0.398 (1.006)
Risk class								
Risk class 2	-0.916 (0.571)	-0.827 (0.561)	-0.820 (0.573)	-0.731 (0.561)	-1.377** (0.629)	-1.141* (0.628)	0.462 (0.887)	0.287 (0.879)
Risk class 3	-0.076 (0.507)	0.015 (0.496)	0.142 (0.515)	0.228 (0.505)	-0.104 (0.536)	0.215 (0.545)	1.180 (0.862)	1.164 (0.868)
Risk class 4	-0.741 (1.108)	-0.659 (1.105)	-0.447 (1.123)	-0.372 (1.122)	-0.979 (1.209)	-0.524 (1.253)	1.098 (1.330)	1.060 (1.340)
Control type								
System revisions	0.692 (0.487)	0.621 (0.483)	0.791 (0.492)	0.729 (0.489)	0.616 (0.560)	0.760 (0.557)	2.183*** (0.622)	2.313*** (0.631)
Emergency inspections	2.751*** (0.618)	2.788*** (0.616)	2.845*** (0.618)	2.891*** (0.614)	1.602** (0.689)	1.699** (0.723)	2.456** (1.203)	2.515** (1.214)
Other controls								
Year	0.423*** (0.082)	0.422*** (0.082)			0.521*** (0.104)		0.290 (0.185)	
Periods^^								
2006 – 2011								
Monitoring classification								
Normal					-3.152*** (0.498)	0.332*** (0.468)		
Items controlled								
5 – 10					0.387 (0.468)	0.332 (0.470)		
10+					-0.563 (0.900)	-0.297 (0.903)		
N	1514	1514	735	735	1400	661	439	397
Log likelihood	-124.67	-124.89	-120.44	-120.64	-92.21	-89.43	-62.52	-62.39
LR chi2 (7)	60.82	60.37	22.29	21.90	97.84	59.19	18.83	15.61
Prob > chi2	0.000	0.000	0.001	0.001	0.000	0.000	0.009	0.016
Pseudo R2	0.196	0.195	0.085	0.083	0.347	0.249	0.131	0.111

* Significant at 10%, ** significant at 5%, *** significant at 1%. Standard errors are reported in parenthesis.
^ The variable 'other controls' is dropped as no severe deviations have been detected by this control type.
^^ The variable period was initially included in model estimations 3C, 3D, 3F and 3H, but was dropped as all severe deviations were found in the period 2006 – 2011.
Dependent variable: 1 = severe deviation detected during the control, 0 = no severe deviation detected during the control.
Reference categories: Oil and gas sector, risk class 1, inspections, 1997 - 2005, particular priority, 0 - 5 items.
See table 5.1. for more details on the variables.

5.3.1. Hypotheses on firm characteristics

Industry

We postulate in *H1c: More severe breaches in oil and gas* that firms in land-based industry have a negative effect on severity of the deviations compared to oil and gas. Although we had to reject hypothesis *H1a: Oil and gas less compliant,* we are still interested in examining whether firms in the oil and gas sector are more likely to have severe deviations. We postulate *H1c* based on the notion that firms in oil and gas generally operate with large-scale operations that by nature present a larger threat to the environment. Unfortunately, the results for *H1c* are inconclusive, since the dummy variable for land-based industry is not significant in any model estimations. It is probable that this is caused by the very small number of observations of severe deviations in the period. However, we will look for patterns in the raw data to see if there have been some tendencies of severe breaches for oil and gas in the period 1997 - 2011. We are aware of the limitations in these results as it does not consider the effect from other factors.

Table 5.7 Distribution of severe deviations across risk classes

	Oil and gas industry	Land-based industry	Total
Severe deviations	3	29	32
No severe deviations	112	1458	1570
Total controls	115	1487	1602
Percentage of controls with severe deviations	2.6%	2.0%	2.0%

As seen in Table 5.7 above, the distribution in the data does not correspond with our assumption. In the period 1997 - 2011, only 32 severe deviations have been detected, and only three of these have been in the oil and gas sector. This means that of all controls in oil and gas, a modest 2.6% found severe deviations. In land-based industry, only 2% of controls detected severe deviations. The percentage is somewhat higher for controls in the oil and gas sector, but we note that there are only 115 observed controls such that the marginal change of one severe deviation is much higher. Although we cannot say anything about *H1c,* it is evident that only 2% of all controls revealed major breaches in the period 1997 - 2011.

Risk class

In *H2c: Less severe deviations in low-risk firms,* we postulate that firms in risk class 3 or 4 are less likely to have severe deviations than firms in risk class 1. However, similar problems arise for this hypothesis as seen in *H1c*. The dummy variables for risk class 3 and 4 are not significant in any of the model estimations. We will therefore investigate the distribution of severe deviations across risk classes. This will not be enough to answer our hypothesis, but it will indicate how risk classes have affected the occurrence of severe deviations in the period 1997 - 2011.

Table 5.8 Distribution of severe deviations across risk classes

	Risk class 1	Risk class 2	Risk class 3	Risk class 4	Total
Severe deviations	14	5	12	1	32
No severe deviations	589	417	495	69	1570
Total controls	602	422	517	70	1602
Percentage of controls with severe deviations	2.3%	1.2%	2.4%	1.4%	2.0%

From the distribution seen in Table 5.8 above, it is clear that 2.3% of controls of firms in risk class 1 have had severe deviations. For firms in the medium risk classes 2 and 3, the result is unexpected, with severe deviations detected in 1.2% and 2.4% of the controls respectively. Controls at firms in risk class 4, on the other hand, have only found one occurrence of severe deviation in the 70 performed controls in the period 1997 - 2011. Although the percentage of controls with severe deviations in risk class 4 is low at 1.4%, we keep in mind that the sample size in this category is small. Again, we acknowledge that this is merely describing previous results, and that we cannot conclude with viable results for hypothesis *H2c*.

Table 5.9 Findings of expected signs for Model 3: Severe deviations

Hypotheses	**Variable**	**Expected sign**	**Reject?**
Firm characteristics			
H1c: More serious breaches in oil and gas	Land-based industry	-	?
H2c: Less severe deviations in low-risk firms	Risk class 3 & 4	-	?

For a detailed description of risk classes, see Table 4.1.
Yes denotes that the null hypothesis is rejected. No denotes that the null hypothesis cannot be rejected.

Although our empirical results for the effect of industry and risk class on severe deviations are inconclusive, Becker (1968) suggests that higher punishment leads to less violations. In NEA's strategy for enforcement and inspection, swift and decisive action against severe deviations is a focal point, and firms caught with severe deviations not only face economic penalties, but also potential criminal charges (NEA, 2013). When it comes to severe deviations, it can be argued that although the economical penalties from NEA vary between different risk classes, the threat of criminal charges is a more substantial one. This threat is the same regardless of firm characteristics, and the punishment firms may receive through the legal system is not bound by NEA's characterizations of firms. This line of thought implies that the occurrence of severe deviations is influenced by the threat of criminal prosecution.

In terms of the severity of the violation, we have established that there is a low presence of major violations. NEA's enforcement strategy is of such character that firms with severe deviations face higher sanctions compared to those firms that merely have deviations. Sanctions are decided based on an evaluation made by the NEA officer, and range from 0 - 1 MNOK. These are fine warnings, and does not include penalties in case of criminal prosecution. Here, previous studies on NEA's panel data reveals that firms were subject to prosecution in approximately 3% of all controls in the period 1992 - 2001 (Nyborg & Telle, 2006). Although the prosecution level is generally low, economic sanctions range based on the level of severity of the violation (NEA; Orvik, 2015). This is in line with the "principle of marginal deterrence" as examined by Shavell (1992). Here, the author suggests that more serious crimes should result in more severe punishment than minor crimes, in order to limit the severity of criminal activity (Shavell, 1992). It is crucial that the regulator, NEA, understands that firms have to make continuous decisions where the dynamics of incentives can affect the severity of the violations.

5.4. Evidence of Harrington paradox

Lastly, we will conclude with a discussion on whether there is evidence of what is much argued within the literature; that there is a higher compliance rate than anticipated by Becker's model (1968) in rational crime theory. We will attempt to answer if this predicament, denoted as the "Harrington paradox", is evident from our data.

Harrington's much discussed paper starts by making three statements;
(i) For most cases the monitoring frequency is low,
(ii) Even when violations are discovered, fines or other penalties are rarely assessed and these are small compared to the cost of complying,
(iii) Yet, it is still evident that firms comply most of the time (Harrington, 1988; p.29).

By a brief look into the regulatory environment surrounding pollution permits in Norway, it may seem as though there is evidence of Harrington's three statements about compliance. Firstly, according to NEA's monitoring frequency, outlined in Table 2.3, it is clear that most firms experience controls less than once a year. Thus, Harrington's first statement is accurate in describing the Norwegian regulatory environment when it comes to non-tradable pollution permits. Further, we know that when violations are detected, NEA in most cases will issue a fine warning where the firm in question is given a time limit to correct the infringement. If the corrections are made and documented within the set time frame, the firm will rarely suffer economic consequences (Orvik; NEA, 2015a). In similarity with the studies performed by Harrington (1988) and other literature on the topic (Walle, 2003; Telle & Nyborg, 2006), we lack data on firms' cost of compliance. However, we consider Harrington's second statement to be applicable to the same extent as in previous studies. Lastly, serious violations are few and far between, and only 2% of the controls performed in the period 1997 - 2011 detected deviations deemed as particularly severe.

However, by examining the results in more detail, it is evident that the paradox dissolves. According to Harrington, there would be an abundance of compliance among Norwegian firms under the conditions stated above. Nonetheless, we see from *Section 4.3. Descriptive statistics* that this is not the case, as 76% of firms are in violation with the permits, and more than 40% of firms have consecutive violations. These findings imply that Harrington's last statement can not be applied to the case of Norwegian firms with pollution permits. The low frequency of severe deviations at first seem to support Harrington's paradox, but after further review, we note that firms face much stricter penalties, as well as threats of prosecution and a loss of reputation, if caught with violations of a more serious manner. Thereby, we conclude that there is a lack of evidence of to establish a "Harrington paradox" among Norwegian firms within oil and gas and the land-based industry in the period between 1997 and 2011. This contributes to already existing Norwegian literature on the subject that have used data from previous years, across several industries (Walle, 2003; Nyborg & Telle, 2006).

6. CONCLUSION

Whether or not firms comply with non-tradable pollution permits hinge on a variety of factors. One can assume that when a firm is facing an environmental regulation, there are several considerations that will account for the decision they will make; such as the nature of their operations, the way in which their permits are inspected, and the potential punishment that follows. In this thesis, we have strived to answer what factors attribute to Norwegian firms' level of compliance with pollution permits, and if these differ by:

i. Firm characteristics
ii. Monitoring methods
iii. The period in which the control was performed

Firm characteristics have been investigated based on the industry the firm belongs to and the Norwegian Environment Agency's risk classification of firms. Both variables have been found to have a significant impact on compliance and consecutive violations. Here, the general tendency is that firms placed in the strictest risk classification will be more induced to comply because of the expected threat of higher sanctions and the greater likelihood of detection. Our results indicate that operating in land-based industry has a negative effect on compliance compared to being in the oil and gas sector. Contrary to our expectations, this indicates that firms in oil and gas are more likely to comply. Additionally, we find that operating in land-based industry positively affect consecutive violations compared to oil and gas, indicating that firms in oil and gas are less likely to have consecutive violations.

When analyzing the effect of risk classifications, we find that being placed in the strictest risk class has a positive effect on compliance compared to lower risk classes. In terms of consecutive violations, the results regarding the risk classification are questionable. Here, we find weak support that being placed in the lowest risk class, risk class 4, has a negative effect on consecutive violations, while the results for risk class 3 are inconclusive. Thus, firms in the strictest risk class tend to outperform the low-risk firms, refuting our hypotheses. We find no evidence that firm characteristics have a significant effect on the severity of violations.

Monitoring methods proved to have a significant impact on compliance. The general tendency in our results regarding monitoring methods is that more thorough and extensive controls have a higher detection rate than the shorter, more superficial inspections. Here, we find that control type, number of controlled items and monitoring category are all relevant predictors. In terms of the chosen control type, our findings reveal that more extensive system revisions have a negative effect on compliance compared to the shorter inspections, indicating that system revisions uncover more violations. Further, we find that less thorough controls in the category ‘other controls’ positively affect compliance compared to inspections, implying that these detect fewer violations. Our findings also indicate that controls where more than five items have been inspected uncover more violations than controls where only 1 - 5 items were inspected, as controls with 6 - 10 and 10+ controlled items both have a negative effect on compliance.

Further, in a dynamic monitoring environment, real compliance decisions are continuous by nature. We find that being placed in the monitoring category of particular priority has a negative effect on compliance compared to normal monitoring, indicating that these firms are more likely to be found in violation with the pollution permits. Here, the results contradict our other findings and we assume this to be due to a causality dilemma. We suspect that the negative influence on compliance is not an effect of the firms being placed under particular monitoring, but rather that the firms are placed under particular priority monitoring as a result of previous non-compliance.

When it comes to the time and period, we find that the results regarding the year the control was performed in are inconclusive. However, our results show that there is a significant effect on compliance in regards to whether the control was performed before or after the early onset of the financial crisis from 2006. We find that the period from 2006 until 2011 has a negative effect on compliance, indicating that firms’ ability to comply with pollution permits decreased in the period around the financial crisis. The same effect was found for consecutive violations, such that firms were more likely to have consecutive violations in the period around the financial crisis than before.

From looking at the three factors that attribute to the level of compliance, we find that more thorough monitoring is an important factor to encourage greater compliance among Norwegian firms. These controls also have the potential to reduce the issue of asymmetric information and incentivize firm transparency due to the increased difficulty for firms to conceal information during longer-lasting and more extensive controls. Additionally, we find that being placed in an industry or risk class where the threat of higher sanctions may increase firms' focus on precautionary measures. Consequently, these firm characteristics may result in a reduced number of violations. Here, the higher expected penalty encompasses the risk of economic sanctions, the potential loss of reputation and the threat of criminal charges.

Although the monitoring frequency is considered to be relatively low in Norway, and few offenders are harshly punished, there is little evidence to confirm a "Harrington paradox", which states that there is more compliance than what can be explained by rational crime theory. From the data, we find that 76% of all controls performed in the period 1997 - 2011 detect non-compliance. Although a minority of these are severe deviations, the high rate of non-compliance in itself is enough to renounce Harrington's notion of paradoxical high compliance rates among Norwegian firms with pollution permits.

7. RECOMMENDATIONS

7.1. Policy implications

Based on our result, it is difficult to conclude with accurate policy recommendations. However, from the findings in this thesis, it seems that the Norwegian Environment Agency should continue its efforts on performing detailed controls with a rigorous hand. In line with their current philosophy, it is important with a clear regulatory presence, which may send a message to the firm that there is an increased risk of being caught if violations indeed occurred. More information about the agent's hidden characteristics would yield more effective monitoring and enforcement methods. Although the nature of direct regulations do not naturally reveal firms abatement cost at the margin, it is discussed in the literature that more thorough controls might induce the agent to invest in more transparent technology, which in turn would lead to a greater probability for detecting violations.

7.2. Limitations and further research

We recognize that there are considerable limitations in the available data. The lack of detrimental variables, such as the cost of compliance, firm size, revenue and moral motivation of firms, limits the viability of our results. Additionally, in our data, violations are classified as either normal or severe deviations. We acknowledge that a more detailed differentiation of the violations would give a better basis for further policy implications. We consider the urgency of the violations, and the level of acuteness of the environmental impact, to be particularly relevant when determining how to monitor and enforce compliance to non-tradable pollution permits.

It is evident from the limitations in this thesis, and from existing literature on the topic, that predicting firms' decision whether to comply with environmental regulations or not is difficult. Ideally, empirical studies on compliance, monitoring and enforcement should include more information about the agent's hidden characteristics, which in turn would yield more effective monitoring and enforcement methods. Thereby, we suggest that there is a need for further research on factors that affect compliance, preferably with a better data sample, including more relevant predictors.

References

Becker, G. (1968). Crime and Punishment: An Economic Approach. *Journal of Political Economy 76*(2), 169–217.

Bye, B. and Klemetsen, M. E. (2014). The impacts of alternative policy instruments on environmental performance. A firm level study of temporary and persistent effects. *(No. 788)*, Oslo: Statistics Norway

Burby, R. J. and Paterson, R. G. (1993). Improving compliance with state environmental regulations. *Journal of Policy Analysis and Management 12*(4), 753-772.

Cohen, M. A. (1987). Optimal enforcement strategy to prevent oil spills: an application of a principal-agent model with moral hazard. *Journal of Law and Economics*, 23-51.

Cohen, M. A. (2000). Monitoring and Enforcement of Environmental Policy. *The International Yearbook of Environmental and Resource Economics*. Edited by H. Folmer and T.Tietenberg, UK: Edward Elgar.

Dechezleprêtre, A., Glachant, M., Haščič, I., Johnstone, N. and Ménière, Y. (2011). Invention and Transfer of Climate Change–Mitigation Technologies: A Global Analysis. *Review of Environmental Economics and Policy*, *5*(1), 109–130.

Gray, W.B. and Deily, M. E. (1996). Compliance and enforcement: Air pollution regulation in the US steel industry. *Journal of environmental economics and management 31*(1), 96-111.

Gray, W. B. and Scholz, J. T. (1991). Analyzing the equity and efficiency of OSHA enforcement. *Law & Policy*, *13*(3), 185-214.

Hahn, R. W. and Stavins, R. N. (1992). Economic Incentives for Environmental Protection: integrating theory and practice. *The American Economic Review*, 464-468.

Harford, J. D. (2000). Initial and Continuing Compliance and the Trade-Off Between Monitoring and Control Costs. *Journal of Environmental Economics and management 40*, 151-63.

Harrington, W. (1988). Enforcement leverage when penalties are restricted. *Journal of Public Economics*, *37*(1), 29-53.

Heyes, A. G. (1994). Environmental Enforcement when Inspectability is Endogenous. *Environmental & Resource Economics 4(*5): 479-494.

Heyes, A. G. (1998). Making things stick: Enforcement and compliance. *Oxford review of economic policy*, *14*(4), 50-63.

Heyes, A.G. and Rickman, N. (1999). Regulatory Dealing - Revisiting the Harrington Paradox. *Journal of Public Economics 72*(3), 361-378.

Heyes, A. G. (2000). Implementing Environmental Regulation: Enforcement and Compliance. *Journal of Regulatory Economics*, *17*(2), 107-129.

ISO (2015). Guidelines for auditing management systems ISO 19011:2011. Retrieved from http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=50675

Klemetsen, M. (2015). Personal communication. February 27th. 2015

Klemetsen, M. E., Bye, B. and Raknerud, A. (2013). Can non-market regulations spur innovations in environmental technologies?. *Conference on the Economics of Innovation and Patenting in Mannheim* (2), 4.

Kruger, J., Oates, W. E., and Pizer, W.A. (2007). Decentralization in the EU Emissions Trading Scheme and Lessons for Global Policy. *Review of Environmental Economics and Policy 1*(1), 112 - 133.

Laffont, J. J. (1995). Regulation, moral hazard and insurance of environmental risks. *Journal of Public Economics*, *58*(3), 319-336.

Ministry of Climate and Environment (2014a). Green shift - climate and environmentally friendly restructuring. Retrieved from https://www.regjeringen.no/en/topics/climate-and-environment/climate/innsiktsartikler-klima/green-shift/id2076832/

Ministry of Climate and Environment (2014b). Tildelingsbrev 2014 for Miljødirektoratet. Retrieved from https://www.regjeringen.no/nb/dokumenter/Tildelingsbrev-2014-for-Miljodirektoratet/id2343220/

Ministry of Climate and Environment (2014c). About the Ministry. Retrieved from https://www.regjeringen.no/en/dep/kld/about-the-ministry/id673/

Ministry of Foreign Affairs (2013). Miljø og klima: Informasjon om Norges miljø-og klimasamarbeid med EU. Retrieved from https://www.regjeringen.no/nb/tema/europapolitikk/tema/miljo-og-klima1/id686218/

Nadeau, L W. (1997). EPA Effectiveness at Reducing the Duration of Plant-Level Noncompliance. *Journal of Environmental Economics and Management 34*(1), 54-78.

NEA (2010).Veiledning til Egenrapportering. TA-2606/2010. Retrieved from http://www.miljodirektoratet.no/old/klif/publikasjoner/andre/1929/ta1929.pdf

NEA (2013). A strategy for inspection and Enforcement (work) 2012-2015. Faktaark M-42-2013. Retrieved from http://www.miljodirektoratet.no/no/Publikasjoner/2014/Februar-2014/A-strategy-for-inspection-and-enforcement-work-2012-2015/

NEA (2015a). About Norwegian Environment Agency. Retrieved from http://www.miljodirektoratet.no/no/Om-Miljodirektoratet/Norwegian-Environment-Agency/

NEA (2015b). Virksomheter med tillatelse. Retrieved from http://www.norskeutslipp.no/no/Listesider/Virksomheter-med-utslippstillatelse/?SectorID=90

NEA; Orvik, R. (2015). Personal communication. February 24th 2015.

Norwegian Pollution Control Act (1981). Lov om vern mot forurensninger og om avtall. LOV-2014-08-29-62. Retrieved from. https://lovdata.no/dokument/NL/lov/1981-03-13-6

Norwegian Pollution Regulations (2004). Regulations regarding to pollution control. FOR-2004-06-01-931. Retrieved from. https://lovdata.no/dokument/SF/forskrift/2004-06-01-931

NPCA (1999). Fastsettelse av gebyr- og kontrollklasse samt endrings kategorier. *SFTs kvalitetssikringssytem*.

NPCA (2001). "SFTs tilsyn i 2000" SFT-rapport TA-1815/2001. Retrieved from http://www.miljodirektoratet.no/no/Publikasjoner/Publikasjoner/2001/Juni/SFTs_tilsyn_i_2000/

Nyborg, K. (2003) "The Impact on Public Policy on Social and Moral Norms: Some Examples" *Journal of Consumer Policy* (December, 2003): 259-277

Nyborg, K. and Telle, K. (2006). Firms' compliance to environmental regulation: Is there really a paradox?. *Environmental and Resource Economics*, *35*(1), 1-18.

OECD (2011). OECD Environmental Performance Reviews: Norway 2011. OECD Publishing. Retrieved from http://dx.doi.org/10.1787/9789264098473-en

Perman, R., Ma, Y., Common, M., Maddison, D. and McKilvary, J. (2011). *Natural resource and environmental economics* (p. 181-191). Harlow, UK: Pearson Education Ltd.

Phillips, P. C. (1986). Understanding spurious regressions in econometrics. *Journal of econometrics*, *33*(3), 311-340.

Porter, M.E. and C. van der Linde (1995) "Green and Competitive: Ending the stalemate" *Business and the Environment- Harvard Business Review* (September/October 1995): 120-33

Rasmusen, E. (1989). Games and Information: An Introduction to Game Theory. New York: Basil Blackwell.

Roberts, P. W. and Dowling, G. R. (2002). Corporate reputation and sustained superior financial performance. *Strategic management journal 23*(12), 1077-1093.

Romstad, E. (2005). Game Theory and Resource Allocation Mechanisms. *Lecture note in ECN 371, NMBU*.

Russell, Clifford S. (1990). Monitoring and Enforcement. *Public Policies for Environmental Protection*. Edited by Paul Portney, Washington DC: Resources for the Future: 261.

Scholz, J. T. (1984). Voluntary compliance and regulatory enforcement. *Law & Policy*, *6*(4)

Shavell, S. (1986). The Judgement Proof Problem. *International Review of Law and Economics 6*(1), 45- 58.

Shavell, S. (1992). A Note on Marginal Deterrence. *International Review of Law and Economics 12*(1): 133-149.

Stafford, S. L. (2002). The effect of punishment on firm compliance with hazardous waste regulations. *Journal of Environmental Economics and Management*, *44*(2), 290-308.

State of the Environment Norway (2015). National Goals and Objectives. Retrieved from http://www.miljostatus.no/miljomal/

Stavins, R. N. (1995). Transaction costs and tradable permits. *Journal of environmental economics and management*, *29*(2), 133-148.

Tietenberg, T. H. (1990). Economic instruments for environmental regulation. *Oxford Review of Economic Policy*. 17-33.

TNS Gallup (2014). Klimabarometeret. Retreived from *http://www.tns-gallup.no/sokeresultat?q=klimabarometer*

Walle, M. A. (2003). Overholder bedriftene i Norge miljøreguleringene? *Report 6/2003*. Oslo: Statistics Norway.

Winter, S. C. and May, P. J. (2001). Motivation for compliance with environmental regulations. *Journal of Policy Analysis and Management*, *20*(4), 675-698.

Appendix I

Table 1A: Correlation matrix

Variables	Compliance	Consecutive violations	Severe deviations	Industry	Risk class	Control type	Year	Period	Monitoring	Items controlled
Compliance	1.000									
Consecutive	-0.269	1.000								
Severe deviations	-0.080	0.055	1.000							
Industry	-0.085	0.122	-0.012	1.000						
Risk class	-0.187	-0.158	-0.004	0.284	1.000					
Control type	0.094	0.042	0.029	-0.080	-0.347	1.000				
Year	-0.092	0.042	0.144	-0.099	0.186	-0.203	1.000			
Period	-0.131	0.030	0.153	-0.100	0.149	-0.205	**0.879**	1.0000		
Monitoring	0.163	-0.085	-0.195	0.028	0.049	-0.145	0.075	0.059	1.000	
Items controlled	-0.152	0.051	-0.018	0.018	-0.002	-0.115	**-0.382**	**-0.373**	-0.045	1.000

The correlation value between year and period has been discussed in *Section 5*.
We also note the correlation values between year and controlled items, as well as period and controlled items. The rule of thumb is that one should be careful in including variables with a correlation value higher than 0.35 in the same regression. However, logistic regressions do not require a complete absence of multicollinearity.

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