June 2023

What Drives Monitoring, Enforcement, and Environmental Compliance? An Empirical Investigation in a Transitional Economy

Abstract: This work analyzes the complete sequence of inspections and compliance of environmental regulations, impositions of fines, payment of fines, and delay of payment in the context of a transitional economy. The analysis is conducted for the case of 6,790 facilities that belong to different economic sectors between the years 2013 and 2019 in Chile. This work demonstrates that inspections and compliance are conducted differently across sectors, and both are related to some specific facilities' characteristics. This paper also displays that the impositions of fines increase the probability of compliance, and that is transmitted as a spillover effect to facilities sharing the same firm owner and in facilities that belong to the same sector located in the same commune. Furthermore, this work shows that presenting a compliance program is less likely on the small size facilities, the severity of the violation correlates positively with the size of the fine, and finally, the fine's payment positively correlates with the size of the facility. This work concludes that monitoring efforts carried out by the regulator in Chile are effective, but relatively low. The main findings of this work may be used the design of enforcement strategies, especially at context that face limited budget and resources.

JEL Codes: K32, K42, Q53, Q58

Keywords: Environmental compliance, enforcement, inspections, penalties, sanctions.

What Drives Monitoring, Enforcement, and Environmental Compliance? An Empirical Investigation in a Transitional Economy

1 Introduction

Monitoring and enforcement are critical components of environmental regulatory compliance. The existing literature supports the idea that enforcement actions, such as inspections and sanctions, affects positively the environmental performance of regulated entities (Gray and Shimshack, 2011; Laplante and Rilstone, 1996; Nadeau, 1997; Shimshack, 2014; Shimshack and Ward, 2005). Most of these studies have been carried out in the developed world. Unfortunately, in the case of low- and middle-income countries, empirical literature that has addressed monitoring, enforcement, and compliance with environmental regulations is scarce. In the context of developing countries, Blackman et al., (2018) points out that regulatory monitoring and enforcement are affected by weak institutions, inconsistency in the written legislation, a high number of informal firms, and lack of access to abatement alternatives to decrease emissions. For example, the related literature in Latin America presents a few empirical studies conducted in Colombia, Uruguay, and Mexico (Briceño and Chávez, 2010; Caffera, 2004; Chakraborti, 2022; Dasgupta et al., 2000; Escobar and Chávez, 2013). These works support the idea that as well as in developing countries enforcement has a significant impact to explain compliance behavior among industrial firms. However, the empirical studies face the challenge of obtaining credible data that is barely verified by the regulator.

In this paper, we analyze empirically the drivers of inspections, compliance, and imposition of sanctions in the context of environmental regulations in Chile. We start our analysis by identifying drivers of inspections carried out by the Chilean Superintendence of

Environment (SMA by its Spanish acronym) over the regulated facilities; then, we study drivers of environmental compliance behavior of the regulated facilities; and finally, we identify drivers of imposition of sanctions carried out by SMA and explore the payment over the regulated sanctioned facilities. The analysis is conducted for the case of facilities that belong to different economic sectors that are regulated by the SMA. The facilities must comply with different environmental regulations in addition to what is established in each environmental operating permit. Our work includes several sectors such as Agroindustry, Fishing, Aquaculture, Mining, Energy, Industrial Factories, Environmental Sanitation, Housing, and Construction. We consider a total of 6,790 facilities belonging to all the geographical areas of continental Chile between the years 2013 and 2019. The SMA carries out a monitoring plan yearly and must prioritize which facilities to visit, given the fact that the number of resources is limited. From the total sample considered in our study, each year the SMA has inspected less than 3% of the total facilities.

Our work is an empirical analysis of the complete sequence of enforcement and compliance in Chile, including inspections, compliance, submission of compliance programs, size of fines, payment of fines, and delay in payment of fines. In conducting our analysis, we recognize that the inspection decisions of the SMA (who to inspect) are not independent of the compliance decisions of the facilities (comply or not comply). Because non-compliance facilities can either face a fine or submit a compliance program to fulfill the environmental regulations during the first stage of the sanctioning procedure, we also analyze what determines to present a compliance program as an intermediate alternative to fulfill the regulations for the facilities found in violation.

Our work contributes to producing new empirical evidence on environmental monitoring, enforcement, and compliance in the context of a transitional economy.[1] We first estimate together both decision of inspection and compliance and then we link that to the imposition of fines, for the same data set. We explore the drivers of fines being imposed on non-compliant facilities and related payments, which have received little attention in the existing empirical literature. We also add to the literature that has explored spillover effects of monitoring and enforcement within sectors and locations. We do so by considering also the possibility of spillover effects on facilities that belong to the same firm. To that purpose, we use the information on the ownership structure of facilities included in our sample.

Our research has produced several new and important results. We find that inspections are carried out differently across sectors and are related to some specific facilities' characteristics. Facilities from Agroindustry, Energy, and Mining sectors are more likely to be inspected than facilities from the sectors of Fishing-Aquaculture and Housing-Construction. Small and large facilities are less likely to be inspected than middle-size. Also, inspections correlate negatively with the age of the facility. The enforcement actions of SMA, as past monitoring and fine imposed, have a positive correlation with developing a new inspection.

Regarding compliance, we found that facilities that belong to Agroindustry, Energy, and Industrial sectors have a higher probability of compliance compared with facilities in the Fishing-Aquaculture and Housing-Construction sectors. We also find that the SMA

[1] World Bank classifies Chile in the group of High-Income Economies. GDP per capita PPP rose from 10,438 in 1992 to 22,767 in 2017 (Figures in 2011 international Dollars. Data from the World Development Indicators https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups). However, we consider Chile as a country still in transition in many aspects, especially in the implementation of the institutional environmental framework that is the topic of this study.

monitoring activities increase the probability of compliance. Another driver of compliance is having received a fine in the past, which also impacts the compliance behavior of facilities sharing the same firm's owner and facilities sharing the same sector and location, as a spillover effect.

We also find that once detected in violation, presenting a compliance program is less likely for small-size facilities than middle and large-size facilities. The severity of the violation correlates positively with using the option of presenting a compliance program. With respect to the impositions of fines, we show that the severity of the violation correlates positively with the size of the fine, and the fine payment positively correlates with the size of the facility.

This paper proceeds as follows: Section 2 briefly discusses the key literature and describes monitoring and enforcement activities to induce environmental compliance carried out by the SMA in Chile. Section 3 presents the details of our methodology and data. Section 4 presents the results. In section 5 we discuss the results and conclude.

2 Key Literature on Monitoring and SMA's Monitoring and Enforcement

In this section, by following the existing literature, we present key aspects of the relationship between an enforcement agency's actions and regulated firms' compliance behavior. Then we describe the monitoring and enforcement activities carried out by SMA in Chile.

2.1 Key Aspects of the Relation Between the Enforcement Actions and Regulated Firms' Compliance

Monitoring and enforcement strategies are key components of environmental regulations. The enforcement agency has limited resources, inspections and sanctioning procedures are costly, then in practice, it must select which facilities and firms to inspect. The existing empirical literature suggests that inspections are related to the compliance history of the facilities, the action of citizen complaints, and the facilities' characteristics (Earnhart, 2004; Eckert and Eckert, 2010; Helland, 1998b; Shimshack, 2014).

The facilities' compliance is affected by the expected actions of the regulator (Cohen, 1987; Dasgupta et al., 2000; Dasgupta et al., 2001). Firms deal with private costs to comply with the regulations and face the probability of being inspected and detected as non-complier. The conventional economic analysis suggests that an individual firm has the incentive to not comply as long as the marginal savings (marginal gains from non-compliance) are larger than the marginal expected cost (fines) of being caught as non-complier (Blackman, 2010). This hypothesis has been evaluated by the empirical literature that has suggested that firms adjust environmental behavior by reacting to inspections, sanctions, or motivated by the fear of being in the sights of the regulator (Shimshack, 2014). Therefore, for a given level of monitoring and enforcement from the regulator, facilities with higher abatement costs have higher incentives to violate regulations, and consequently are likely to exhibit lower environmental compliance (Stranlund, 2013).

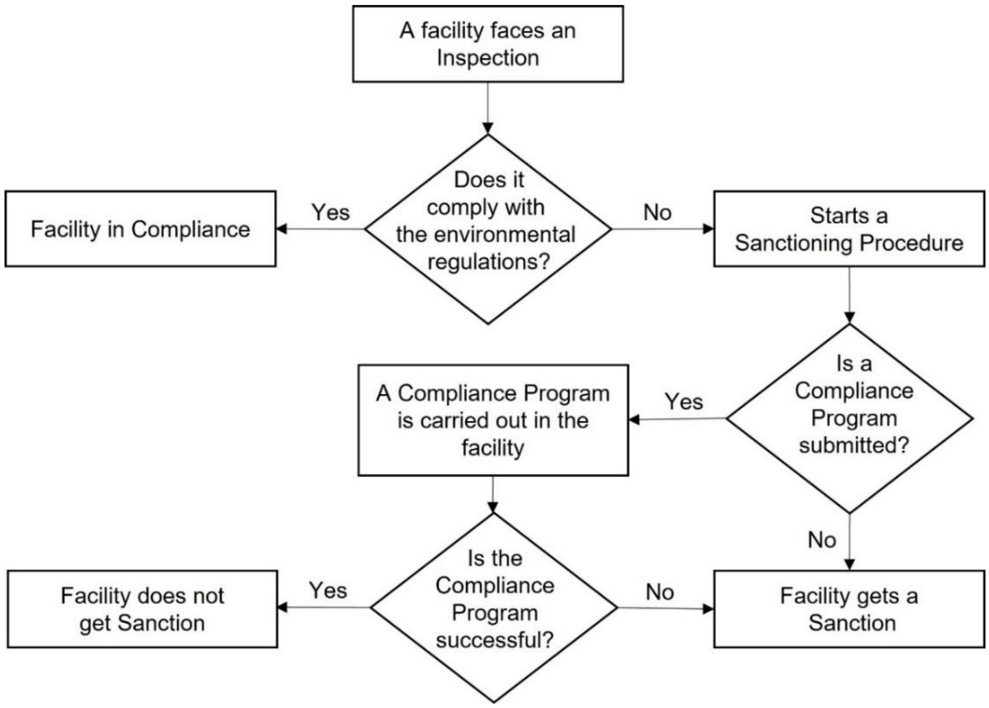
The regulator might impose sanctions after detecting violations of environmental regulations. The sanctioning procedures vary according to specific administrative law and regulations. For example, from the experience documented in The United States and by the EPA guidelines, penalties need to be severe enough in order to serve as a deterrent but also need to treat violators fairly and equitably (US Agency Environmental Protection, 2020). In support of the EPA's actions, light sanctions such as warning letters, phone calls, and notices of violation are developed by lower-level authorities. Instead, more severe sanctions can be carried out by courts at the regional, state, or federal level (Shimshack, 2014). The impositions of sanctions depend on factors such as facility characteristics, the damage caused by the violations, and the economic benefits obtained from that (Earnhart, 2009; Shimshack, 2014). Rousseau (2019) also shows that fines are higher for relapsed violators as well as for intentional offenses. To the best of our knowledge, there is a gap in the existing literature regarding what determines the payment of fines from sanctioned facilities.

2.2 Description of the Enforcement Activities Carried out by SMA in Chile

The SMA is responsible for executing, organizing, and coordinating the monitoring of environmental regulation in Chile. The SMA began its activities in 2010 but its sanctioning activities started at the end of 2012 (SMA, 2018). The SMA carries out environmental inspections on facilities, promotes environmental compliance, and imposes sanctions if the entities fail to comply with environmental regulations. Figure 1 shows a simplified diagram that represents the SMA's procedure for environmental enforcement in the Chilean context. As shown in Figure 1, if a facility violates a regulation and is detected, it has the possibility to submit a compliance program to the SMA to fulfill the environmental regulations during the first stage of the sanctioning procedure. If this program is successful, the facility obtains environmental compliance.[2]

[2] Article 42 of Law Num. 20,417 that regulates the SMA, establishes that once a sanctioning procedure has been initiated, the facility has the option to present a compliance program within a 10-day period. A compliance program is a plan of action and goals to comply with environmental regulations in a period set by the SMA. In case of non-compliance with this program, the sanctioning procedure will continue with a potential fine of up to twice the amount corresponding to the original infraction. If the facility does not accept the sanctioning process, it has the possibility to prosecute claims against the SMA in the Environmental Courts (SMA, 2018).

Figure 1. Monitoring and Enforcement Process of Environmental Regulations in Chile



Source: Own elaboration.

According to the existing environmental law, Chilean facilities must typically have to comply with a set of different existing specific environmental regulations. Most of these are related to command-and-control (CAC) instruments such as emission standards, ambient quality standards where facilities are located, prevention and/or decontamination plans; and economic incentives-instruments such as emissions taxes. However, the SMA must also monitor the environmental permits[3], and these represent more than 16,000 different instruments (SMA, 2018).[4]

[3] *Resoluciones de Calificación Ambiental* or just RCA for its acronym in Spanish for environmental permits.
[4] The SMA must monitor compliance of each RCA held by a given facility. Facilities may have more than 1 environmental permit. Among facilities with RCA, 83% have only 1 RCA, 15% have between 2 RCAs and 5 RCAs; and 2% have more than 6 RCAs (SMA, 2018).

The SMA has indicated that its monitoring actions consider the environmental risk, the territory, and the specific characteristics of the facilities and their processes (SMA, 2018). The level of complexity of the facilities is related to the number of environmental instruments that the project faces and to the number of environmental permits that the project has obtained.[5] Non-compliant facilities may be sanctioned at the end of a sanctioning procedure. Available sanctions include three categories. i) written warnings, ii) fines, and iii) temporary or definitive closure. The Law Num. 20,417 that regulates the SMA, establishes that sanctions must be set according to the characteristics of the infractions.[6] Moreover, the Law also indicates that the number of people affected (or potentially affected) by the violation, the compliance history of the facility involved, and the economic impact of the penalty on the violator could also be considered to determine the level of the penalty being imposed.[7]

3. Methodology and Data

In this section, we present econometric models to identify drivers of SMA's inspection and facilities' compliance, the determinants of fines, their payment by sanctioned facilities, and the delay of fines payments. We also analyze the intermediate decision of a facility detected in violation that presents a compliance program. At the end of this section, we describe our unique set of data used in this work.

---

[5] Details about the SMA description about environmental monitoring are available in: https://portal.sma.gob.cl/wp-content/uploads/2018/11/Estrategia-de-Fiscalizacion-Ambiental-2018-2023.pdf

[6] From Law Num. 20,417 that regulates the SMA, the article 36 establishes that infractions are classified into three categories: i) minor; ii) serious; and iii) very serious.

[7] The SMA guidelines establish that the imposition of sanctions by the SMA is proportional to the nature of the infraction. Details in https://portal.sma.gob.cl/index.php/download/bases-metodologicas-para-la-determinacion-de-sanciones-ambientales-2017

3.1 Specification for Inspections and Compliance: A Simultaneous Estimation

Our aim is to identify drivers of inspections from the SMA and drivers of individual facility compliance. The problem of asymmetric information between the regulator and the facilities regarding compliance behavior motivates the SMA to conduct inspections. The SMA only knows the compliance status of a facility after it is inspected. We addressed this in our empirical model as a sample selectivity problem. For that, we explore a bivariate probit model with sample selection, which is also called a censored probit or model with partial observability.

Restrictions on observability applied to bivariate probit models are described by Poirier (1980), Meng and Schmidt (1985), and Helland (1998). For our empirical analysis, we estimate, by maximum-likelihood, probit models with sample selection using the heckprobit model from Stata.[8] We analyze jointly both decisions about the inspection (SMA's decision) and the compliance (facility's decision) due to the selectivity problem between monitoring and compliance. Equation 1 shows the specification for the inspection carried out by the SMA and equation 2 shows the specification for the facility's compliance. We first estimate both equations separately and then simultaneously address the selection problem.

$$INSP_{itr} = \begin{cases} 1, & facility\ is\ inspected\ if\ \ INSP^{*}_{itr} \geq 0 \\ 0, & facility\ is\ not\ inspected\ if\ \ INSP^{*}_{itr} < 0 \end{cases} \quad (1)$$

where:

[8] Details on https://www.stata.com/manuals/rheckprobit.pdf

$$INSP_{itr}^{*} = \sum_{j=1}^{6} \alpha_j^1 SECTOR_{ijt} + \sum_{k=1}^{2} \gamma_k^1 SIZE_{ikt} + \sum_{l=1}^{4} \delta_l^1 ZONE_{lit} + \sum_{m=1}^{6} \theta_m^1 YEAR_{imt} + \beta_1^1 AGE_{it}$$
$$+ \beta_2^1 INSP_{it-1} + \beta_3^1 REPORT_{it-1} + \beta_4^1 NON\_COMPL\_3YEAR_{it}$$
$$+ \beta_5^1 FINED\_L3YEAR_{it} + \beta_6^1 COMPL\_PROGM_{it} + \beta_7^1 LOG\_POPULATION_{it}$$
$$+ \beta_8^1 LOG\_POVERTY_{it} + \beta_9^1 PRIOR\_ZONE_{it} + \beta_{10}^1 NUM\_INST_{it}$$
$$+ \beta_{11}^1 \beta LOG\_BUDGET\_SMA_{itr} + \beta_{12}^1 \; LOG\_NUM\_FACILITIES\_REG_{itr} + \varepsilon_{itr}^1$$

$$COMP_{it} = \begin{cases} 1, & facility\ complies\ if\ \ COMP_{it}^{*} \geq 0 \\ 0, & facility\ \ does\ not\ complies\ if\ \ COMP_{it}^{*} < 0 \end{cases} \quad (2)$$

where:

$$COMP_{it}^{*} = \sum_{j=1}^{6} \alpha_j^2 SECTOR_{ijt} + \sum_{k=1}^{2} \gamma_k^2 SIZE_{ikt} + \sum_{l=1}^{4} \delta_l^2 ZONE_{lit} + \sum_{t=m}^{6} \theta_m^2 YEAR_{mit} + \beta_1^2 AGE_{it}$$
$$+ \beta_2^2 INSP_{it-1} + \beta_3^2 REPORT_{it-1} + \beta_4^2 NON\_COMPL\_3YEAR_{it}$$
$$+ \beta_5^2 FINED\_L3YEAR_{it} + \beta_6^2 LOG\_POPULATION_{it} + \beta_7^2 LOG\_POVERTY_{it}$$
$$+ \beta_8^2 NUM\_INST_{i} + \beta_9^2 SPILLOVER_{it} + \varepsilon_{it}^2$$

$INSP_{itr}^{*}$ and $COMP_{it}^{*}$ are latent variables related to inspection and compliance, respectively; where *i* denotes the facility, *t* denotes the year and *r* denotes the region where the facility is located $SECTOR_{jit}$ is a set of seven dichotomous indicators according to the following classification: i) Fishing-Aquaculture, as an omitted category; ii) Environmental Sanitation; iii) Housing-Construction; iv) Energy; v) Agroindustry; vi) Mining; and vii) Industrial Factories. $SIZE_{kit}$ indicates the size of the facility according to the information provided by "*Servicio de Impuestos Internos*". It denotes a set of three dichotomous indicators following the categories: i) Small and Micro, ii) Middle, as an omitted category; and iii) Large. $ZONE_{lit}$ denotes a set of the 5 macrozones in which we have divided the continental territory of Chile: i) Norte Grande (NG); ii) Norte Chico (NCH); iii) Chile Central (CEN); iv) Centro Sur (CES); and iv) Sur (SUR), as omitted category. $YEAR_{mit}$ a set of seven dichotomous indicators following the 7 years of our analysis from 2013 to 2019. The variable AGE_{it} is a proxy for the age of the facility, calculated from the date that the environmental permit (RCA) was obtained up to the year that this analysis was done. The variable $INSP_{it-1}$ is a dichotomous indicator with $INSP_{it-1} = 1$ to denote if the facility was inspected the period before, and $INSP_{it-1} = 0$ otherwise. The variable $REPORT_{it-1}$ is a dichotomous indicator with $REPORT_{it-1} = 1$ if the facility has self-reported information to the SMA concerning environmental regulation (*Examen de Información*) during the last past period, and $REPORT_{it-1} = 0$ otherwise. The variable $NON\_COMPL\_3YEAR_{it}$ is a dichotomous indicator with $NON\_COMPL\_3YEAR_{it} = 1$ to denote if the facility was found in environmental non-compliance in the last 3 years, and $NON\_COMPL\_3YEAR_{it} = 0$ otherwise. The variabl*e* $FINED\_L3YEAR_{it}$ is a dichotomous indicator with $FINED\_L3YEAR_{it} = 1$ to denote if the facility received a fine in the last 3 years, and $FINED\_L3YEAR_{it} = 0$ otherwise. The variable $COMPL\_PROGM_{it}$ is a dichotomous indicator with $COMPL\_PROGM_{it} = 1$ to denote if the facility is operating under a compliance program during the current period, and $COMPL\_PROGM_{it} = 0$. The variable $LOG\_POPULATION_{it}$ is the population (log) of the commune where the facility is located. The variable $LOG\_POVERTY_{it}$ is the percentage of poverty (log) at the commune where the facility is located. The variable $PRIOR\_ZONE_{it}$ is a dichotomous indicator with $PRIOR\_ZONE_{i} = 1$ to denote if the facility is located in an area that is prioritized by the SMA. The variable NUM_INST_{it} indicated the number of environmental instruments that the facility must fulfill. The variable $LOG\_BUDGET\_SMA_{itr}$ is the national budget (log) that the

SMA has each year to implement its environmental regional control strategy. The variable $LOG\_NUM\_FACILITIES\_REG_{itr}$ is the number of facilities (log) in each region that the SMA potentially may inspect. The variable $SPILLOVER_{it}$ is a set of three dichotomous indicators denoting the enforcement action of the SMA over related facilities that share firm owners, facilities that belong to the same economic sector, and facilities located nearby.

3.2 Sanctioning Procedure and the Alternative to Present a Compliance Program

According to the procedures of the SMA, detected non-compliant facilities have the possibility to present a compliance program to avoid a sanction. We are interested in exploring the drivers of that decision. Because only non-compliant facilities must decide whether to present a compliance program, our sample is not random, and is biased toward noncompliance facilities. A natural alternative to deal with the sample selection is by performing a Heckman-style correction, but this strategy requires that the outcome of interest is a continuous variable.[9] Another alternative is controlling for a variable related to non-compliance, for example, the predicted probability of non-compliance that can be calculated from the output of the previous estimations (equation 1 and equation 2). We present in this section a generic specification to obtain the determinants of presenting a compliance program, that considers one ad-hoc control variable to deal with this bias. Despite its limitations, we explore the Inverse Mills Ratio (IMR_i) and the probability of non-compliance (equal to $1 - Pr\ (COMP_i = 1)$) as regressors. Equation 3 presents the empirical model to

[9] Heckman (1979) discusses the bias that results from using nonrandomly selected samples to estimate behavioral relationships as an ordinary specification error or omitted variables bias. Heckman selection models implement firstly, a selection equation that is binary, and secondly, an unbiased estimation for a continuous outcome of interest. In our case, the selection equation (being non-compliance facility) is a binary variable; however, our outcome of interest (presenting a compliance program) also is a binary variable. Alternatively, we may explore as outcome variable the cost of the program, that is a continues variable, but it changes our original question of what determine to present a compliance program.

explore what determines that a facility presents a compliance program after being found in violation.

$$COMP\_PROG_i = \begin{cases} 1, & facility\ present\ program\ if\ \ COMP\_PROG_i^* \geq 0 \\ 0, & facility\ \ does\ not\ present\ program\ if\ \ COMP\_PROG_i^* < 0 \end{cases} \tag{3}$$

where:

$$\begin{aligned} COMP\_PROG_i^* = & \sum_{j=1}^{6} \alpha_j^3 SECTOR_{ij} + \sum_{k=1}^{2} \gamma_k^3 SIZE_{ik} + \sum_{i=1}^{4} \delta_l^3 ZONE_{il} + \sum_{m=1}^{6} \theta_i^3 YEAR_{mi} \\ & + \beta_1^3 AGE_i + \beta_2^3 LOG\_POPULATION_i + \beta_3^3 LOG\_POVERTY_i \\ & + \beta_4^3 NUM\_INFRACTIONS_i + \beta_5^3 LOW\_INFRACTION_i \\ & + \beta_6^3 MIDDLE\_INFRACTIONS_i + \beta_7^3 HIGH\_INFRACTIONS_i + \beta_8^3 RELAPSE_i \\ & + \beta_9^3 COMPLAINT_i + \beta_{10}^3 NUM\_INST_i + \beta_{11}^3 CORRECTION_i + \varepsilon_i^3 \end{aligned}$$

$COMP\_PROG_i^*$ is the latent variable of presenting a compliance program. From this level, we model as cross-section estimates. The variables $SECTOR_i$, $SIZE_i$, $ZONE_i$, $YEAR_t$, AGE_i, $LOG\_POPULATION_i$, $LOG\_POVERTY_i$, and NUM_INST_i come from previous equations. We add four new variables regarding the severity of the impact caused by the violation. The variable $NUM\_INFRACTIONS_i$ denotes the number of infractions established in the sanctioning process.[10] $LOW\_INFRACTIONS_i$ is a dichotomous indicator with $LOW\_INFRACTIONS_i = 1$ to denote that at least one of the infractions is classified as low impact infraction, and $LOW\_INFRACTIONS_i = 0$ otherwise. $MIDDLE\_INFRACTIONS_i$ is a dichotomous indicator with $MIDDLE\_INFRACTIONS_i = 1$ to denote that at least one of

[10] During the sanctioning procedure is established with detail the number of infractions incurred by the facility. Each infraction may be classified according to the level of damage or impact on the environment.

the infractions is classified as middle impact infraction, and $MIDDLE\_INFRACTIONS_i = 0$ otherwise. $HIGH\_INFRACTIONS_i$ is a dichotomous indicator with $HIGH\_INFRACTIONS_i = 1$ to denote that at least one of the infractions is classified as high impact infraction, and $HIGH\_INFRACTIONS_i = 0$ otherwise.[11] We also add the variable $RELAPSE_i$ that is a dichotomous indicator with $RELAPSE_i = 1$ to denote that the facility faced a sanctioning procedure before the submission of the compliance program, and $RELAPSE_i = 0$ otherwise. In this level, we know if the sanction procedure has been related to a complaint from the community near the facility. We include the dichotomous indicator $COMPLAINT_i$ as an explanatory variable to denote if the inspection that uncovered the sanctioned violation was motivated by a community complaint.[12] The variable $CORRECTION_i$ is included to deal with the selection problem.[13]

3.3 Imposition of Sanctions: Level of Fines and Payment

According to the procedures of the SMA, non-compliant facilities may be sanctioned at the end of a sanctioning procedure. Our purpose is to analyze what determines the size of the fines defined by the SMA. We focus on fines since, during the study period, more than 95% of the sanctions imposed on non-compliant facilities correspond to fines.[14] In this part

---

[11] We explore a continuous variable to capture environmental damage. Specifically, we construct the variable Impact Index for the environmental damage, which is defined as:
Impact Index = 1(Num. of Low Infractions) + 2*(Num. of Middle Infractions) + 3* (Num. of High Infractions).*

[12] Unfortunately, we do not at the beginning of our analysis if the inspection that uncover the sanctioned violation was motivated by a community complaint. We only know that if the facility has a sanction process.

[13] As mentioned before, to correct for selection bias we use the predicted probability that a facility is non-compliant and also the IMR.

[14] The normative framework of the Law Num. 20,417 that regulates SMA, establishes that one fine related to one infraction can range from 0 to 10,000 U.T.A. (7 million USD). However, one facility may have several infractions at the same time in the same sanction procedure.

of the sequence, we have first the condition of being detected in violation, and then the imposition of a fine.[15] Equation 4 presents our model for the sizes of the fine.

$$FINE_i = \sum_{j=1}^{6} \alpha_j^4 SECTOR_{ij} + \sum_{k=1}^{2} \gamma_k^4 SIZE_{ik} + \sum_{l=1}^{4} \delta_l^4 ZONE_{il} + \sum_{m=1}^{6} \theta_m^4 YEAR_{im} + \beta_1^4 AGE_i$$
$$+ \beta_2^4 LOG\_POPULATION_i + \beta_3^4 LOG\_POVERTY_i$$
$$+ \beta_4^4 NUM\_INFRACTIONS_i + \beta_5^4 LOW\_INFRACTION_i$$
$$+ \beta_6^4 MIDDLE\_INFRACTIONS_i + \beta_7^4 HIGH\_INFRACTIONS_i$$
$$+ \beta_8^4 RELAPSE_i + \beta_9^4 COMPLAINT_i + \beta_{10}^4 NUM\_INST_i + \beta_{11}^4 COMP\_PROG_i$$
$$+ \beta_{12}^4 PRIOR\_ZONE_i + \beta_{13}^4 IMR_i + \varepsilon_i^4 \quad (4)$$

where:

$$FINE_i \geq 0$$

$FINE_i$ is a left-censored dependent variable indicating the size of the fine imposed on the facility *i* (in thousand USD, starting from 0).[16] The explanatory variables have been previously described. The variable IMR_i is included to deal with the selection problem from the previous stage of inspection. To estimate $FINE_i$ we propose a tobit model to deal with the left censoring. Once the fine is set by the SMA, the facility must pay to continue with their operation (facility's decision). Considering this, we also explore two additional specifications to analyze the probability that the fine is paid and how long it takes for the facility to pay the fine. We estimate equation 5 as a probit model and equation 6 as a double-censored tobit model for the amount of the fine and the number of days for the facility to pay the fines, respectively.

---

[15] In this case, the outcome of interest is a continuous variable therefore we use Heckman selection model.
[16] Fines are set in the Annual Tax Unit (UTA by its Spanish acronym) in real terms for each year. In this study we use the conversion that 1 UTA is equal to 705 USD.

$$PAID_i \quad = \begin{cases} 1, & facility\ pays\ the\ fine\ if\ \ PAID_i^* \geq 0 \\ 0, & facility\ \ does\ not\ pay\ the\ fine\ if\ \ PAID_i^* < 0 \end{cases} \tag{5}$$

where:

$$PAID_i^* = \sum_{j=1}^{6} \alpha_j^5 SECTOR_{ij} + \sum_{k=1}^{2} \gamma_k^5 SIZE_{ik} + \sum_{l=1}^{4} \delta_l^5 ZONE_{il} + \sum_{m=1}^{6} \theta_m^5 YEAR_{im} + \beta_1^5 AGE_i$$
$$+ \beta_2^5 RELAPSE_i + \beta_3^5 COMPLAINT_i + \beta_4^5 NUM\_INST_i + \beta_5^5 PRIOR\_ZONE_i$$
$$+ \beta_6^5 FINE_i + \beta_7^5 IMR_i + \varepsilon_i^5$$

$$PAY\_DELAY_i = \sum_{j=1}^{6} \alpha_j^6 SECTOR_{ij} + \sum_{k=1}^{2} \gamma_k^6 SIZE_{ik} + \sum_{i=1}^{4} \delta_l^6 ZONE_{il} + \sum_{m=1}^{6} \theta_m^6 YEAR_{im} \tag{6}$$
$$+ \beta_1^6 AGE_i + \beta_2^6 RELAPSE_i + \beta_3^6 COMPLAINT_i + \beta_4^6 NUM\_INST_i$$
$$+ \beta_5^6 PRIOR\_ZONE_i + \beta_6^6 FINE_i + \beta_7^6 IMR_i + \varepsilon_i^6$$

where:

$$M > \ PAY\_DELAY_i \ \geq 0.$$

The variable $PAID_i^*$ is the latent variable for the payment of the fine. The variable PAY_DELAY_i *i*s a double-censored dependent variable indicating the days taken for the facilities before the payment. We consider two values of M, equal to 365 days and 730 days. The variable IMR_i is included in both equations using the same procedure as before with the same limitations.

3.4 Data Set

The main source of our data is the National Environmental Inspection Information System (SNIFA by its Spanish acronym).[17] The SNIFA presents a detailed description in

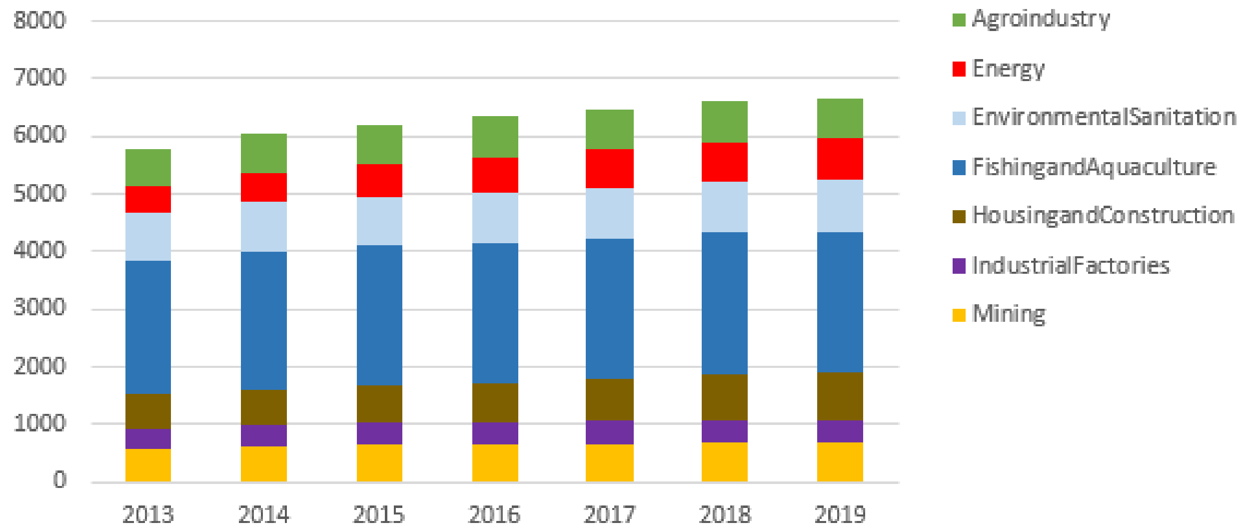
[17] The SNIFA is an open-access portal available at https://snifa.sma.gob.cl/

terms of "*Unidad Fiscalizable"* (UF) which is equivalent to facilities in our study. An UF is a "physical unit in which actions and processes are regulated by one or more instruments of SMA competence" (SMA, 2018). We include in our analysis facilities that meet at least one of the following three conditions[18]: i) belong to Agroindustry, Fishing, Aquaculture, Mining Energy, Industrial Factories, Environmental Sanitation, Housing and Construction, ii) have at least one environmental permit for operation[19]; and iii) are subject to compliance with water emissions.[20] Following these criteria, our study considers a total of 6,670 facilities operating during the period 2013-2019.[21]

Figure 2 shows the total number of facilities and the distribution by sector of activity through the study period. New facilities enter operation yearly. We consider the first year of a facility's operation as the year in which it obtained the environmental permit. We assume that the facility will continue in operation until the end of our analysis. Moreover, we also assume that, during the studied period, there is no change in individual characteristics such as size, property, or geographic location. At the end of the year 2019, the distribution of facilities in our sample by sector is the following: Fishing and Aquaculture (37%), Environmental and Sanitation (13%), Housing and Construction (12%), Energy (11%), Agroindustry (11%), Mining (10%), and Industrial Factories (6%).

[18] These criteria exclude facilities with significate lower environmental impact as supermarkets, restaurants, schools, or churches that may have been connected with any environmental instrument as the standard for noise or for being inside the zone of an air quality plan.
[19] *Resolución de Calificación Ambiental* (RCA). In our data, 97% of the facilities in our sample have at least 1 RCA.
[20] Supreme Decree 460/2002 and Supreme Decree 90/2000 for wastewater discharges.
[21] We built a unique set of data for our study. Even though any part of the information used in this work is public, we obtain the data by web-scraping the SNIFA portal using a suitable software such as MATLAB. Details for scraping data from the web on: https://blogs.mathworks.com/loren/2017/07/10/web-scraping-and-mining-unstructured-data-with-matlab/#0b4dd3c5-8737-47ca-b0b0-0cf5c43ed2da

Figure 2. Number of Facilities by Sector per Year, from 2013 to 2019



Source: Own elaboration.

Table 1 shows the number of facilities in each sector and the subset that has been inspected at least once for each year, during the period 2013 -2019.[22] The total number of facilities inspected each year represents between 2.2% and 2.9% of the total facilities regulated by the SMA during this period, with a minimum of 140 facilities inspected in 2015 up to a maximum of 187 facilities inspected in 2019. In the last year of the period under analysis, the Mining sector had 44 facilities inspected and presents the highest proportion of facilities inspected that year (6.4%). The sector Housing-Construction had only 3 facilities inspected during 2019, representing the lowest proportion of inspected facilities during that period (0.2%). The sector Fishing-Aquaculture had 31 facilities inspected in 2019, but it is a low proportion (1.3%) considering the total number of facilities that belong to that sector.

[22] We do not classify it as an inspection activity such as self-reporting emissions. Nor do we classify as inspection the remote pollutants measurements or the study of satellite images, which we know the SMA has begun to implement in recent years.

Table 1. Number of Facilities and Proportion that are Inspected by Sector per Year

Sectors and Years		2013	2014	2015	2016	2017	2018	2019
Agroindustry	Num. Facilities [a]	657	672	683	692	702	712	716
	Inspected Facilities [b]	25	38	21	31	44	24	44
	Proportion [c]	3.8%	5.7%	3.1%	4.5%	6.3%	3.4%	6.1%
Energy	Num. Facilities	446	506	569	612	646	684	706
	Inspected Facilities	21	15	23	22	29	36	23
	Proportion	4.7%	3.0%	4.0%	3.6%	4.5%	5.3%	3.3%
Environmental Sanitation	Num. Facilities	833	846	860	872	880	890	893
	Inspected Facilities	30	24	21	25	22	27	24
	Proportion	3.6%	2.8%	2.4%	2.9%	2.5%	3.0%	2.7%
Fishing-Aquaculture	Num. Facilities	2,322	2,386	2,420	2,439	2,449	2,454	2,459
	Inspected Facilities	37	36	28	16	21	23	31
	Proportion	1.6%	1.5%	1.2%	0.7%	0.9%	0.9%	1.3%
Housing-Construction	Num. Facilities	604	623	646	681	728	781	806
	Inspected Facilities	0	2	1	1	4	6	2
	Proportion	0.0%	0.3%	0.2%	0.1%	0.5%	0.8%	0.2%
Industrial Factories	Num. Facilities	364	384	391	393	399	406	407
	Inspected Facilities	23	18	11	15	20	17	19
	Proportion	6.3%	4.7%	2.8%	3.8%	5.0%	4.2%	4.7%
Mining	Num. Facilities	566	613	640	652	661	679	683
	Inspected Facilities	31	36	35	30	25	40	44
	Proportion	5.5%	5.9%	5.5%	4.6%	3.8%	5.9%	6.4%
Total	Num. Facilities	5,792	6,030	6,209	6,341	6,465	6,606	6,670
	Inspected Facilities	167	169	140	140	165	173	187
	Proportion	2.9%	2.8%	2.3%	2.2%	2.6%	2.6%	2.8%

Source: Own elaboration based on information from SNIFA.
Note:
[a] Num. Facilities shows the number of facilities per sector included in our study for each year.
[b] Inspected Facilities shows the number of different facilities inspected each year. If a facility is inspected more than once during the same year, it is counted only once in that year.
[c] Proportion is the product from *(Inspected Facilities) *100 / (Num. Facilities)*.

Table 2 shows the aggregate figures regarding inspected facilities and their outcomes by sector during the period of our study. From the 754 facilities that were inspected during the period 2013-2019, 538 were compliant while the other 216 were found in violation. This suggests that the rate of compliance during the studied period is about 71%, while 29% of the inspected facilities were found in violation during the same period. We notice that the sectors that show higher compliance are Industrial Factories, Energy, and Agroindustry, and sectors with more violations are Housing-Construction, Environmental Sanitation, and Fishing-Aquaculture.

Table 2. Inspected Facilities and Compliance Outcomes by Sector During 2013-2019

Sectors	Inspected Facilities [a] (1)	Compliance [b] (2)	Non-Compliance [c] (3)
Agroindustry	156	114 (73%)	42 (27%)
Energy	109	86 (79%)	23 (21%)
Environmental Sanitation	114	74 (65%)	40 (35%)
Fishing-Aquaculture	152	102 (67%)	50 (33%)
Housing-Construction	14	5 (36%)	9 (64%)
Industrial Factories	75	61 (81%)	14 (19%)
Mining	134	96 (72%)	38 (28%)
Total	754	538 (71%)	216 (29%)

Source: Own elaboration based on information from SNIFA.
Note:
[a] Inspected Facilities shows the total number of facilities in each sector inspected at least once during the 2013-2019 period.
[b] Compliance shows the number of facilities found in compliance always.
[c] Non-Compliance shows the number of facilities found in non-compliance at least once. In parentheses are the proportions in each status, with base the column 1. In this table *Inspected Facilities = Compliance + Non-Compliance.*

Table 3 shows figures regarding inspected non-compliance facilities, compliance programs, and facilities fined during the period of our study. From the 216 facilities found in violation, 191 facilities presented a compliance program and 68 were fined during the same period. These figures also include the results of sanctioning procedures that were started before 2013 and some that were not finished at the end of our analysis; therefore, we are not able to compare the proportion among columns of this table. Sectors of Fishing-Aquaculture, Agroindustry, and Environmental Sanitation present a higher number of non-compliance facilities and a higher number of compliance programs submitted. Sectors of Mining and Agroindustry show more facilities being fined.

Table 3. From Non-Compliance to Facilities Fined During 2013-2019

Sectors	Non-Compliance [a] (1)	Compliance Programs Submitted [b] (2)	Facilities Fined [c] (3)
Agroindustry	42	38	13
Energy	23	19	7
Environmental Sanitation	40	37	12
Fishing-Aquaculture	50	46	7
Housing-Construction	9	6	1
Industrial Factories	14	11	12
Mining	38	34	16
Total	216	191	68

Source: Own elaboration based on information from SNIFA.
Note:
[a] Non-Compliance shows the number of facilities found in non-compliance at least once during the 2013-2019 period. For some facilities of this group, the sanctioning procedure is still ongoing up to the last year of our sample period.
[b] Compliance Programs Submitted shows the number of facilities that had submitted a compliance program after being found in violation in the period of our study. A subset of this group has a compliance program that was still in progress at the end of our study period.
[c] Facilities Fined shows the number of facilities that had been fined in this period. This group includes facilities that had not presented a compliance program and facilities that failed in the implementation of the compliance program. The balance among columns does not hold, since some processes started before 2013 or finished after 2019, outside our period of analysis.
In the table *Non-Compliance ≠ Compliance Program Submitted + Facilities Fined*.

A special characteristic of the observed units in our analysis is that one facility may be controlled by more than one firm and one firm may own more than one facility. In our data, 12% of the units (772 facilities) have multiple firms as their owner. We also identify a total of 4,191 different firms controlling the total sample of facilities. To explore potential spillover effects among these facilities we link facilities that have the same owner firm. Consequently, we create 481 networks joining the facilities that have connections with others (3,561 facilities).[23] In this way, each facility belongs to only one network. We also add facilities without connection with others (3,109) as networks of one unique node, then we obtain in total of 3,590 networks. The construction of these networks has two direct

[23] In Chile, one firm is identified by its Unique Tax Identification number (RUT from its Spanish acronym). It could be the case that a firm has operations with different RUTs. Unfortunately, we are not able to identify these relationships in our sample.

implications in our analysis. First, we can cluster robust standard errors using the network as a cluster, under the assumption that there is correlation in the error of our estimations among facilities that are members of the same network. Second, we can analyze spillover effects among facilities that belong to the same network. In Appendices 1 to 8 we show more details about our data and what these networks look like. There we present two specific examples in detail for the Mining and Fishing-Aquaculture sectors to give a better understanding of these relationships.

4 Results

In this section, we present the main results of our study. First, we show the results of the joint model for inspections and compliance. Second, we present the estimation incorporating the spillover effect in the compliance of facilities with the same owner firm and in facilities that belong to the same sector located in the same location. Third, we show the results regarding drivers of the submission of a compliance program. Fourth, we present the results of our analysis for the size, payment, and delay of payment of imposed fines.

4.1 Results for Simultaneous Estimation of Inspections and Compliance

Table 4 shows the results for the joint model of inspections and compliance. Column 1 and column 2 present the estimation coefficients. Appendix 9 presents in detail the marginal effects for each explanatory variable. The results suggest that consistent with the number of inspections previously analyzed, the probabilities of inspection faced by facilities are very low and vary across sectors. Using the sector Fishing-Aquaculture as the base of comparison, 5 sectors present a higher probability of inspection (the increase in probabilities for each sector are: Agroindustry 0.0233, Industrial Factories 0.0164, Mining 0.0161, Energy 0.0155, Environmental Sanitation 0.0151). Regarding the location of the facilities, our results suggest that facilities in the northern part of the country face a higher probability of inspection, with the macrozone south as the base (being located in Norte Grande, increases the probability of inspection by 0.0122). Smaller facilities and larger facilities face a lower probability of inspection than middle-size facilities as a base, but low in magnitude. Analyzing the variables related to history for enforcement and compliance, we find that facilities fined in the past are more likely to face an inspection (increase in a probability of 0.021), and facilities having a compliance program in operation, that also means found in non-compliance in the past, show a higher probability of facing an inspection (increase in a probability of 0.031). Similarly, being located in a prioritized area increases the probability of inspection, but is low in magnitude. The variable related to SMA resources, such as regional budget, or the number of potential facilities to inspect in the region, correlates positively to the facility's probability of facing an inspection, but both have no significant estimates. Finally, the variable age shows that older facilities face a lower probability of being inspected. The social variables related to poverty and density correlate positively with the probability of inspection but are not significant. We also find that the variable number of the instrument correlates positively to inspections but is low in magnitude.

We also estimate the drivers of compliance. Our results suggest that conditioned on the decision of inspection, the expected probability of compliance is low and varies across sectors. Using as the base of comparison the sector Fishing-Aquaculture, 5 sectors present a higher probability of compliance (the increase in probabilities for each sector are: Agroindustry 0.0151, Energy 0.0122, Industrial Factories 0.0116, Mining 0.0106, Environmental Sanitation 0.0067). With respect to the geographical zone, facilities located in the north of Chile present a higher probability of compliance (increase in a probability of

0.014) than facilities in the south. The relation between size and compliance shows no significant effect in our estimates. The variable age shows that older facilities comply with less probability but is very low in magnitude. This result could be explained because older facilities may face higher benefits from violations (for example, higher abatement costs), or different awareness/culture on their environmental responsibility. The social variables related to poverty and density are not significant. We find that enforcement actions of the SMA, such as the imposition of fines and the self-reporting requirement, have a positive effect on compliance (both actions present an increase in the probability of about 0.013). We also find that the variable number of the instruments correlates positively to compliance but is low in magnitude.

Table 4 also shows the significance of parameter related to the correlation between the error terms between equation 1 (inspections) and equation 2 (compliance), therefore our results confirm that the selectivity problem biases the estimation if it is done separately.

Table 4. Coefficient Estimates for the Joint Estimation of Inspection and Compliance

VARIABLES	(1) Inspection		(2) Comply
Predicted probability	0.025		0.014
Sectors (base: Fishing-Aquaculture)			
Agroindustry	0.465***		0.449***
	(0.0842)		(0.0952)
Energy	0.347***		0.404***
	(0.0879)		(0.106)
Environmental Sanitation	0.340***		0.242***
	(0.0857)		(0.0864)
Housing-Construction	-0.278**		-0.485***
	(0.119)		(0.155)
Mining	0.357***		0.356***
	(0.0949)		(0.0940)
Industrial Factories	0.363***		0.381***
	(0.0977)		(0.0999)
Age	-0.0149***		-0.0112**
	(0.00418)		(0.00502)
Size (base: Medium): Micro and Small	-0.132**		-0.0882
	(0.0552)		(0.0694)
Large	-0.162***		-0.0843
	(0.0498)		(0.0613)
LogPoverty	0.0664		0.0594
	(0.0444)		(0.0490)
LogDensity	0.00426		0.0219
	(0.0124)		(0.0139)
Inspection_lastyear	0.393***		0.459***
	(0.0744)		(0.0778)
Report_lastyear	0.257***		0.457***
	(0.0614)		(0.0800)
AnyViolation_3y	0.350***		-0.118
	(0.0720)		(0.0782)
Fined_3y	0.438***		0.420**
	(0.163)		(0.176)
Compliance Program	0.634***		
	(0.0666)		
Prioritized Area	0.0780***		
	(0.0298)		
Macrozone (base: SUR)			
NGR	0.223*		0.405***
	(0.123)		(0.100)
NCH	0.138		0.182*
	(0.103)		(0.0937)
CEN	-0.0105		-0.0738
	(0.0852)		(0.105)
CES	0.0353		0.0391
	(0.0746)		(0.0893)
Num. Instruments	0.0698***		0.0460***
	(0.0136)		(0.0101)
LogSMABudgetperFacility	0.0365		
	(0.0655)		
logNumFacilitiesRegion	0.000329		
	(0.0598)		
Constant	-2.196***		-2.563***
	(0.366)		(0.160)
Athrho		3.419***	
		(0.985)	
Controlled per Year	YES		YES
Observations	37,425		37,425

Source: Own elaboration based on information from SNIFA.
Note: Standard errors clustered by networks of facilities with common owners; *** p<0.01, ** p<0.05, * p<0.1

4.2 Spillover Effect on Compliance

We estimate again our model for inspection and compliance as in the previous section, adding spillover explanatory variables in the compliance equation.[24] We consider three dichotomous variables to explore the potential effect on a facility's compliance from a fine that was imposed to another connected facility. The first dichotomous variable accounts for facilities with at least one Unique Tax Identification number in common (RUT from its Spanish acronym). The second dichotomous indicator accounts for the network of facilities connected to different RUTS that own one facility (In Appendices 1 to 8, we show more details about our data and what these networks look like). Finally, we repeat the same procedure, but for facilities that belong to the same sector and same location (commune). In our data, these indicators had the value of one when the SMA imposed a sanction within the last three years to the connected facilities.[25]

Table 5 shows the coefficient estimates for the variables related to imposition of fines on individual compliance. Average marginal effects are reported in Appendix 10. We keep the variable fined_3y in all the models because it denotes specific deterrence, that is, the improvement in compliance due to a fine imposed at the same facility. Model 1 shows the improvement in compliance due to fines imposed in the same firms (estimates indicates that it is about 0.013).[26] Adding the spillover effect variables, model 2 shows a positive and significant but small effect on compliance due to the imposition of fines on a facility related to the same RUT (the estimated increase in the probability to comply is 0.006). We do not find any spillover effect for facilities in the same network (model 3). Also, we do not detect

---

[24] We are analyzing potential effects of actions by the SMA on facilities' compliance; therefore, we do not show the estimates for inspections. However, the estimation considers both equations, in the same way as we did in the previous section.

[25] The sanctioning process over facilities demands several months, in most cases more than 1 year. Therefore, we think 3 years behind is a reasonable period to analyze the potential spillover effects.

[26] The model 1 used as reference in Table 5 is the same model shown in the last section (Table 4 and Appendix 9).

an effect for the imposition of fines on facilities in the same location or sector (model 4 and model 5). However, model 6 shows a positive and significant but small effect on compliance due to the imposition of fines on a facility from the same economic sector and location at the same commune (the increase in the probability to comply is estimated to be 0.003). In Appendix 11, we show marginal effects for the rest of the variables for both the inspection and compliance equations. The sign and magnitude of these effects do not change with the inclusion of the spillover variables.

In summary, we find that fines have a specific deterrence effect on average greater (twice in magnitude) than the general deterrence effect. Furthermore, sharing the same owner is more relevant than sharing the same economic sector and location regarding the spillover effects on compliance.

Table 5. Spillover Variable Coefficient Estimates of Fines on Comply

VARIABLES [a]	(1)	(2)	(3)	(4)	(5)	(6)
Fined_3y	0.0134**	0.0131**	0.0134**	0.0133**	0.0135**	0.0136**
	(0.00551)	(0.00551)	(0.00551)	(0.00553)	(0.00549)	(0.00552)
AnyFine_SameOwner3y		0.00585***				
		(0.00219)				
AnyFine_SameNet3y			-1.05e-05			
			(0.00147)			
AnyFine_Sector3y				0.00223		0.00219
				(0.00208)		(0.00215)
AnyFine_Comune3y					-0.000600	-0.00173
					(0.000854)	(0.00106)
AnyFine_SectorComune3y						0.00335**
						(0.00153)
Other Controls	YES	YES	YES	YES	YES	YES
Observations	37,425	37,425	37,425	37,425	37,425	37,425

Source: Own elaboration based on information from SNIFA.
Note:
Standard errors clustered by networks of facilities with common owners; *** p<0.01, ** p<0.05, * p<0.1
[a] Inspection not presented in this table.

4.3 Drivers of Presenting a Compliance Program

Table 6 shows the results regarding the decision to present a compliance program once the facility has been found in violation. We present coefficient estimates for six models. Average marginal effects are presented in Appendix 12. The first three models differ in how the severity of the violation is measured. The last three models consider all the variables related to the violation. Model 1 and model 4 do not consider bias correction for sample selection. Model 2 and model 5 use the IMR correction, and model 3 and model 6 consider the probability of noncompliance. All the models show the same subset of variables relevant to present a compliance program.

Using the sector Fishing-Aquaculture as the basis, our results show no significance of the variable sector for the decision to present a compliance program. We find that smaller facilities face a lower probability of presenting this program than middle-size facilities as a base (decrease in the probability of -0.335 in model 2 and -0.324 in model 5). Facilities located in central south (CES) show a lower probability (decrease in the probability of -0.217 in model 2 and -0.229 in model 5) to present a compliance program than facilities located in the south, as a base of comparison. The social variable poverty shows a positive effect on the decision of presenting the program (increase in the probability of 0.908 in model 2 and 0.108 in model 5), but with a significance of 10%. Our results show a positive relation between the severity of the violation and the probability to present this program. Facilities with violations that include a serious infraction (category high infraction) are more likely to present the compliance program (increase in the probability of 0.220 in model 5).

Table 6. Coefficient Estimates for Probability of submitting a Compliance Program

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Predicted probability	0.7789	0.7791	0.7726	0.7792	0.7804	0.7733
Sectors (base: Fishing-Aqua.)						
Agroindustry	-0.365	0.138	-0.137	-0.370	0.185	-0.103
	(0.393)	(0.461)	(0.413)	(0.390)	(0.473)	(0.414)
Energy	0.502	0.414	0.756	0.486	0.328	0.728
	(0.614)	(0.640)	(0.660)	(0.612)	(0.660)	(0.653)
Environmental Sanitation	0.496	0.535	0.863	0.519	0.497	1.042*
	(0.483)	(0.580)	(0.585)	(0.473)	(0.568)	(0.602)
Mining	-0.334	-0.609	-0.247	-0.280	-0.401	-0.102
	(0.459)	(0.476)	(0.484)	(0.473)	(0.515)	(0.512)
Industrial Factories	-0.464	-0.222	-0.232	-0.414	-0.0753	-0.0794
	(0.444)	(0.504)	(0.455)	(0.441)	(0.526)	(0.460)
Size (base: Medium)						
Micro and Small	-1.293***	-1.329***	-1.249***	-1.234***	-1.343***	-1.198***
	(0.375)	(0.401)	(0.386)	(0.376)	(0.411)	(0.396)
Large	-0.0427	0.316	0.0450	-0.0443	0.324	0.0774
	(0.264)	(0.277)	(0.273)	(0.274)	(0.290)	(0.298)
Macrozone (base: SUR)						
NGR	0.00893	0.786	0.534	-0.108	0.721	0.483
	(0.480)	(0.504)	(0.505)	(0.486)	(0.508)	(0.515)
NCH	0.360	0.807	0.685	0.390	0.764	0.876
	(0.556)	(0.529)	(0.550)	(0.574)	(0.556)	(0.569)
CEN	-0.607	-0.621	-0.581	-0.679	-0.733	-0.643
	(0.524)	(0.560)	(0.534)	(0.539)	(0.595)	(0.568)
CES	-1.198**	-1.028*	-1.106**	-1.260**	-1.146*	-1.274**
	(0.508)	(0.566)	(0.538)	(0.511)	(0.604)	(0.570)
Age	-0.00710	-0.0158	-0.00838	0.000727	-0.0148	-0.000208
	(0.0265)	(0.0304)	(0.0277)	(0.0286)	(0.0326)	(0.0290)
LogPoverty	0.477*	0.515*	0.441	0.532*	0.583*	0.557*
	(0.272)	(0.304)	(0.291)	(0.285)	(0.320)	(0.318)
LogDensity	0.0706	0.129	0.0647	0.0674	0.122	0.0505
	(0.0782)	(0.0836)	(0.0801)	(0.0761)	(0.0839)	(0.0774)
ImpactIndex	0.0112	0.0147	0.0169			
	(0.0210)	(0.0221)	(0.0207)			
Num_Infractions				0.0236	0.0141	0.0207
				(0.0321)	(0.0326)	(0.0301)
LowInfraction				-0.191	0.0755	-0.0222
				(0.456)	(0.500)	(0.507)
MiddleInfraction				-0.215	-0.246	-0.209
				(0.295)	(0.373)	(0.315)
HighInfraction				0.669*	1.187***	1.587***
				(0.401)	(0.448)	(0.553)
Relapse	-1.027***	-0.664*	-0.962***	-1.048***	-0.625*	-1.055***
	(0.315)	(0.368)	(0.328)	(0.311)	(0.375)	(0.335)
Complaint	-0.165	-0.0542	-0.0947	-0.204	-0.0357	-0.141
	(0.271)	(0.293)	(0.279)	(0.281)	(0.311)	(0.299)
Num. Instruments	-0.0275	-0.00619	-0.00528	-0.0291	-0.00647	-0.0139
	(0.0350)	(0.0406)	(0.0427)	(0.0353)	(0.0419)	(0.0441)
IMR		-14.49***			-15.66***	
		(3.063)			(3.261)	
PNONCOMP			-4.575			-5.115*
			(2.891)			(3.047)
Constant	0.400	5.782***	0.377	0.372	6.145***	0.119
	(0.834)	(1.505)	(0.871)	(0.866)	(1.484)	(0.906)
Year Fixed Effect	YES	YES	YES	YES	YES	YES
Observations	193	192	184	193	192	184

Source: Own elaboration based on information from SNIFA.
Note: Standard errors clustered by facilities ownership in parentheses *** p<0.01, ** p<0.05, * p<0.1

In our first three models, we do not find a relation using the impact index for the environmental damage. We find that facilities that have a relapse on detected violations have a lower probability to present a compliance program (decrease in the probability of -0.127 in model 2 and -0.116 in model 5), but only with a significance of 10%. Finally, the variables that account for the selection problem are relevant to our analysis according to the significance of IMR and PNONCOMP.

We carried out an alternative analysis using the logarithm of the compliance program cost as dependent variable. Table 7 shows the results. We present coefficient estimates for four models. The first two models differ in how the severity of the violation is measured. The last two models consider all the variables related to the violation. Model 1 and model 3 do not consider bias correction for sample selection. Model 2 and model 4 use the IMR correction. All the models show the same subset of variables relevant to present a compliance program.

Using the sector Fishing-Aquaculture as the basis, our results show that the sector of Environmental Sanitation, Energy and Mining present compliance program with higher costs. As before, we find differences in size. Those smaller facilities present programs with lower cost. Our results show a positive relation between the severity of the violation and the cost of the compliance programs though the variable Impact Index for model 1 and 2, and though the variable Number of Infractions for model 3 and 4. Finally, our analysis shows that the compliance program has higher cost when the sanction procedure is motivated by a community complaint.

Table 7. Determinants of the Compliance Program Cost (logCost)

VARIABLES	(1) LogCost	(2) LogCost	(3) LogCost	(4) LogCost
Sectors (base: Fishing-Aqua.)				
Agroindustry	0.936	0.984	0.941	0.978
	(0.726)	(0.725)	(0.729)	(0.742)
Energy	1.736**	1.702**	1.612**	1.596**
	(0.670)	(0.680)	(0.650)	(0.659)
Environmental Sanitation	1.924***	1.896***	1.925***	1.905***
	(0.636)	(0.638)	(0.678)	(0.683)
Housing-Construction	0.422	0.363	0.274	0.236
	(0.730)	(0.797)	(0.961)	(0.974)
Mining	1.653**	1.574**	1.544**	1.498**
	(0.653)	(0.681)	(0.680)	(0.702)
Industrial Factories	0.698	0.696	0.660	0.659
	(0.721)	(0.716)	(0.726)	(0.724)
Size (base: Medium)				
Micro and Small	-1.692***	-1.706***	-1.531**	-1.543**
	(0.646)	(0.645)	(0.681)	(0.684)
Large	0.628*	0.610	0.629*	0.620
	(0.362)	(0.370)	(0.374)	(0.378)
Macrozone (base: SUR)				
NGR	-0.546	-0.504	-0.632	-0.601
	(0.632)	(0.658)	(0.645)	(0.676)
NCH	-0.918	-0.896	-0.862	-0.843
	(0.711)	(0.728)	(0.741)	(0.753)
CEN	-0.656	-0.710	-0.749	-0.773
	(0.695)	(0.725)	(0.698)	(0.726)
CES	-0.877	-0.896	-1.006	-1.012
	(0.702)	(0.707)	(0.721)	(0.725)
Age	0.0190	0.0233	0.0340	0.0361
	(0.0374)	(0.0382)	(0.0430)	(0.0433)
LogPoverty	-0.265	-0.255	-0.223	-0.217
	(0.293)	(0.295)	(0.295)	(0.298)
LogDensity	0.0458	0.0582	0.0523	0.0604
	(0.0989)	(0.107)	(0.106)	(0.115)
ImpactIndex	0.0987***	0.0998***		
	(0.0328)	(0.0329)		
Num_Infractions			0.106**	0.106**
			(0.0494)	(0.0490)
LowInfraction			-0.351	-0.323
			(0.712)	(0.723)
MiddleInfraction			0.133	0.147
			(0.362)	(0.374)
HighInfraction			0.770	0.763
			(0.555)	(0.575)
Relapse	-0.0403	0.0164	-0.112	-0.0709
	(0.692)	(0.711)	(0.681)	(0.709)
Complaint	1.218***	1.184***	1.211***	1.192***
	(0.332)	(0.346)	(0.350)	(0.362)
Num. Instruments	0.0673	0.0699	0.0748	0.0769
	(0.0622)	(0.0627)	(0.0629)	(0.0636)
IMR		-1.157		-0.916
		(4.268)		(4.422)
Constant	1.770	2.116	1.725	1.994
	(1.087)	(1.977)	(1.256)	(2.023)
Year Fixed Effect	YES	YES	YES	YES
Observations	170	169	170	169
R-squared	0.378	0.378	0.374	0.373

Source: Own elaboration based on information from SNIFA.

Note: Standard errors clustered by facilities ownership in parentheses *** p<0.01, ** p<0.05, * p<0.1

4.4 Results for Estimation of Fines

Table 8 shows the results for the estimation of drivers for the fine size. We present coefficient estimates for a tobit model that incorporates the IMR variable created from the joint estimation of inspections and compliance. Similar to the previous section, we present two models that differ in how the severity of the violation is considered. The results of our first model suggest, using the sector Fishing-Aquaculture as the basis, that the Mining sector receives fines on average 1,083 thousand USD higher, with a significance of 5%. In our second model, this figure is similar in sign and magnitude but decreases in significance. However, the second model also shows that sector Industrial Factories receive fines on average 908 thousand USD lower than Fishing-Aquaculture, with a significance of 10%. Regarding zone, both models show that Norte Chico presents higher fines on average at around 1,406 (significance of 1%) and 1,122 (significance of 5%) in thousand USD. Both models show that older facilities receive lower fines. That is a decrease of -67.9 thousand USD per year in the first model (significance of 5%) and a decrease of -91.39 thousand USD per year in the second model (significance of 1%). An important result is for both models the severity of the violation correlates positively with the fine. The total number of infractions and having at least one high-level of infraction increases the fine an average of 153,2 and 1,558 thousand USD respectively. Using our index, we find that one additional low-level infraction increases the fine an average of 119,6 thousand USD; increasing 1 middle-level infraction (that counts as 2 low-level infractions) the fine increases an average of 239,2 thousand USD; and increasing 1 high-level infraction (that counts as 3 low-level infractions) the fine increases an average of 358,8 thousand USD. Surprisingly, we also find that complaints from the community decrease the fine by an average of -689,7 and -750.0 thousand USD for model 1 and model 2 respectively. We speculate that the community complains as soon as the environmental violations are perceived, which would prevent further impacts. The variable Number of the Instruments is a proxy of the complexity of the facilities and also, we understand it as the number of dimensions that the facility may potentially do damage to the environment. This variable correlates positively in both models with the fines increasing an average of 60.6 and 58.6 thousand USD respectively. Finally, the variable IMR that accounts for the selection problem is relevant to our analysis.

Table 8. Coefficient Estimates for the Size of Fines

VARIABLES		(1) Fines in 1000 USD	(2) Fines in 1000 USD
Sectors	Agroindustry	-610.2	-561.6
(base: Fishing & Aqua.)		(377.7)	(368.0)
	Energy	470.1	504.7
		(550.5)	(561.2)
	Environmental Sanitation	-529.2	-224.9
		(447.2)	(434.3)
	Housing and Construction	-272.0	-2,132
		(1,374)	(1,462)
	Mining	973.5*	1,083**
		(531.5)	(519.9)
	Industrial Factories	-908.0*	-756.5
		(459.7)	(460.0)
Size	Micro and Small	-66.10	129.3
(base: Medium)		(355.0)	(355.0)
	Large	-123.1	28.30
		(294.4)	(293.1)
Macrozone	NGR	575.8	-83.51
(base: SUR)		(501.1)	(531.7)
	NCH	1,122**	1,406***
		(478.6)	(480.8)
	NCH	867.8*	606.3
		(443.6)	(433.1)
	CEN	733.0*	608.6
		(436.3)	(435.8)
Age		-91.39***	-67.90**
		(29.49)	(29.67)
LogPoverty		-486.0*	-288.7
		(286.6)	(292.2)
LogDensity		29.76	15.53
		(62.01)	(61.99)
Compliance Program		7.375	-83.48
		(247.1)	(242.1)
Num_Infractions			153.2***
			(28.31)
LowInfraction			-928.6*
			(475.7)
MiddleInfraction			-471.9
			(338.1)
HighInfraction			1,558***
			(519.3)
ImpactIndex		119.6***	
		(18.15)	
Relapse		-29.88	-163.8
		(263.3)	(257.6)
Complaint		-750.0***	-689.7**
		(254.0)	(269.2)
Num. instruments		58.58*	60.56*
		(32.37)	(31.51)
PrioritizedArea		413.1	316.0
		(303.6)	(292.0)
IMR		6,419**	6,114**
		(2,979)	(3,008)
Constant		-735.2	-483.0
		(1,630)	(1,653)
Year Fixed Effect		YES	YES
Observations		79	79

Source: Own elaboration based on information from SNIFA.
Note: Standard errors clustered by facilities ownership in parentheses *** p<0.01, ** p<0.05, * p<0.1

4.5 Results for Drivers of Payment and Delay in Payment

We now turn our attention to the analysis regarding determinants of fine payments and the delay in payment. We present coefficient estimates for three models in Table 9. The first model analyzes fines paid in less than one year since the fine was notified to the facility. Model 2 analyzes fines paid in less than two years, and model 3 analyzes fines paid in less than three years. In all models, we incorporate the IMR variable. Marginal effects are presented in Appendix 13. Our models do not show differences among sectors regarding the payment of fines. We identify that the category large (as dichotomous indicators for size) increases the probability of payment in comparison with the facilities that are not large. This result is expected since these categories have been defined from the information about sales. Large facilities increase the probability of payment (increase in a probability of 0.307 in model 1, 0.220 in model 2, and 0.248 in model 3). Being located in the central south decreases the probability of the facility's payment (decrease in a probability of -0.283 in model 1, -0.356 in model 2, and -0.316 in model 3). Our results show that an increase of 1 year in the variable age decreases the probability of payment (decrease in a probability of -0.024 in model 1, a significance of 10%). Finally, the variable IMR is not significant may be due to the lower sample of units in this level (n=77).

For the delay in payment in days, Table 10 shows results for three estimated models. The first model analyzes delays in payment for fines paid in less than one year since the fine was notified. Model 2 and model 3 consider the delay in payment for fines paid in less than two years and three years respectively. We found that the size of the fine correlates with the delay but in a small magnitude. An additional 100 thousand USD in the level of the fine increases by 1.4 days the delay (significance at 5%) in model 1. We also find a significant correlation in the variable sector. Using the sector Fishing-Aquaculture as the basis, we find that sector Agroindustry delays in addition 83 days more than this base in model 1 and 280 days for model 3; and the sector Energy has an additional 129 days more than the sector Fishing-Aquaculture. Finally, the variable IMR is not significant maybe due to the lower sample of units in this level (n=58).

Table 9. Coefficient Estimates and Average Marginal Effects for Payment of Fines

VARIABLES	(1) Fine paid in 1 year or less	(3) Fine paid in 2 year or less	(5) Fine paid in 3 year or less
Predicted probability	0.627	0.652	0.690
Fine_1000USD	-2.22e-06	3.63e-05	0.000138
	(0.000109)	(0.000148)	(0.000234)
Sectors (base: Fishing & Aqu.)			
Agroindustry	-0.167	0.00338	0.626
	(0.576)	(0.612)	(0.665)
Energy	0.354	0.0537	
	(0.908)	(0.964)	
Environmental Sanitation	-0.583	-0.659	-0.877
	(0.630)	(0.666)	(0.691)
Housing and Construction	-	-	-
Mining	-0.235	-0.0485	-0.311
	(0.714)	(0.793)	(0.933)
Industrial Factories	1.161	0.837	0.420
	(0.772)	(0.832)	(0.909)
Large	1.144**	0.832*	1.071*
	(0.456)	(0.505)	(0.625)
Macrozone (base: SUR)			
NGR	-0.747	-1.384	-1.766*
	(0.806)	(0.899)	(1.046)
NCH	-0.143		
	(0.637)		
CEN	-0.176	-0.947	-1.198
	(0.574)	(0.626)	(0.764)
CES	-1.025*	-1.394**	-1.510**
	(0.563)	(0.623)	(0.729)
Age	-0.0904*	-0.0268	0.0253
	(0.0496)	(0.0510)	(0.0517)
Relapse	0.0270	0.281	0.131
	(0.413)	(0.462)	(0.581)
Complaint	0.241	0.372	0.904
	(0.414)	(0.434)	(0.609)
Num. Instruments	0.0420	0.0880	0.197**
	(0.0437)	(0.0583)	(0.0952)
IMR	2.532	-0.357	0.744
	(2.699)	(3.132)	(3.325)
Constant	0.475	0.988	-0.761
	(1.309)	(1.606)	(1.612)
Year Fixed Effect	YES	YES	YES
Observations	77	69	65

Source: Own elaboration based on information from SNIFA.
Note: Standard errors clustered by facilities ownership in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 10. Coefficient Estimates Payment Delay of Fines

VARIABLES	(1) Payment delay fines paid in 1 year or less	(2) Payment delay fines paid in 2 years or less	(3) Payment delay fines paid in 3 years or less
Fine_1000USD	0.0136**	0.0163	0.0125
	(0.00651)	(0.0154)	(0.0246)
Sectors (base: Fishing & Aqua.)			
Agroindustry	85.78**	119.1	280.4**
	(37.55)	(88.32)	(135.9)
Energy	128.7**	80.92	286.5*
	(49.21)	(114.0)	(163.4)
Environmental Sanitation	-20.57	6.382	33.22
	(42.26)	(86.24)	(140.2)
Housing and Construction	-102.8	-57.68	241.7
	(95.83)	(237.3)	(379.0)
Mining	-46.18	10.55	107.8
	(48.06)	(96.31)	(154.9)
Industrial Factories	-9.219	18.73	-48.87
	(39.40)	(90.91)	(144.6)
Large (dichotomous indicator)	30.60	-53.20	-141.3
	(23.98)	(56.73)	(85.24)
Macrozone (base: SUR)			
NGR	-19.57	-99.88	-310.6
	(53.29)	(126.5)	(200.0)
NCH	-44.83	-103.5	-226.8
	(45.00)	(86.97)	(138.2)
CEN	-28.49	-147.8*	-135.6
	(34.02)	(73.11)	(118.3)
CES	-27.40	-95.39	-75.09
	(33.93)	(80.80)	(125.4)
Age	0.994	5.804	14.88
	(2.942)	(6.738)	(10.32)
Relapse	-31.72	-24.29	-76.02
	(21.86)	(49.96)	(74.47)
Complaint	13.15	25.55	46.72
	(20.79)	(49.57)	(74.38)
Num. Instruments	3.023	6.942	9.521
	(2.948)	(7.055)	(11.22)
Year 2014	-0.690	-76.97	-61.13
	(28.47)	(68.08)	(108.9)
Year 2015	-53.10	-11.94	-39.08
	(33.58)	(75.62)	(122.9)
Year 2016	-30.90	-132.7	152.7
	(34.05)	(79.79)	(104.7)
Year 2017	241.5***	171.6	344.8
	(72.44)	(176.0)	(281.5)
Year 2018	-53.91	57.05	24.97
	(65.51)	(156.9)	(251.7)
Year 2019	98.37	116.5	-41.13
	(74.48)	(180.7)	(291.4)
IMR	-357.9	-1,227**	-175.7
	(251.8)	(560.4)	(862.4)
Constant	161.3	564.9**	-33.64
	(116.3)	(271.4)	(408.8)
Observations	49	54	58

Source: Own elaboration based on information from SNIFA.
Note: Standard errors clustered by facilities ownership in parentheses *** p<0.01, ** p<0.05, * p<0.1

5 Discussions and Conclusions

This work presents several new results regarding monitoring, enforcement, and environmental compliance in Chile. We find that the monitoring effort from SMA is relatively low and that inspections are driven differently across sectors and are related to some specific characteristics of the facilities. Facilities from sectors of Agroindustry, Energy, and Mining are more likely to be inspected than facilities from sectors of Fishing-Aquaculture and Housing-Construction. Facilities in the north of Chile face inspections with a higher probability than facilities in the south. Small and large facilities are less likely to be inspected than middle-size. Inspections correlate negatively with the age of the facility. The enforcement action of SMA has a positive correlation with conducting a new inspection. Facilities fined in the past and the fact of having a compliance program in operation increase the probability of being inspected. We also find that the focus of the inspections is higher on facilities regulated with a higher number of instruments (as several environmental permits) and located in prioritized areas.

As for compliance behavior, the results indicate that sectors of Agroindustry, Energy, and Industrial Factories have a higher probability of compliance compared with Fishing-Aquaculture and Housing-Construction. Again, facilities located in the north of Chile have higher compliance. We also find that SMA monitoring increases the probability of compliance. Another driver of compliance is having received a fine in the past. That also impacts the compliance of facilities sharing the same firm owner and sharing the same sector and location, as a spillover effect. Our results also find that complex facilities with several environmental instruments have a higher propensity to comply.

Our study also shows that presenting a compliance program is less likely for small-size facilities than for middle and large size facilities. Compliance programs carry several activities such as planning, submission in a limited time, and future internal follow-up of this plan. These may bring relatively high costs for a small facility. On the contrary, for larger facilities, these costs may be relatively low since large facilities may have already the capacity (as administrative personnel, engineers, layers, etc.) and the experience to deal with these programs. We find that facilities located in the south use more of that option than facilities in the central south. This may be due to the possibility that facilities located in south of the country perceive a low probability of being inspected and for them it is cheaper to fulfill the regulation using the compliance program after being caught in non-compliance, instead of doing it from the beginning of its operations. The severity of the violation correlates positively with presenting a compliance program. We do not know in detail the social costs, or the private benefits generated from the violations, but we can speculate that greater environmental damage generates also greater profits, then the facilities could have the incentive of not complying, and then implement a compliance program at a relatively low cost in comparison with the private benefits obtained. We understand that the compliance programs are an opportunity for violators to invest in environmental control and fulfill the regulations, as the SMA also stands. However, we speculate that some facilities could be playing the game "investing only after being caught" and that situation may have a large opportunity cost in terms of the annual SMA budget.

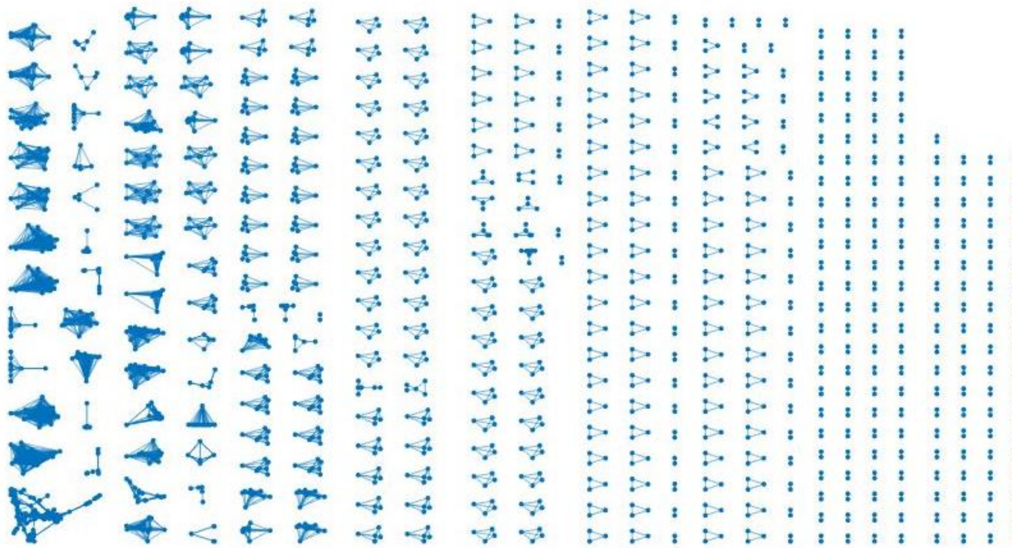
Imposed fines appear to be higher for detected non-compliant facilities in the Mining sector as compared with facilities in Fishing-Aquaculture. Also, imposed fines appear to be higher on facilities located in the north of the country. We also find that the severity of the violation correlates positively with the size of the fine, and the fine payment positively correlates with the size of the facility. Regarding the delay in the payment, we find that the sectors Agroindustry and Energy delayed more days in payment than the sector Fishing-Aquaculture.

The SMA must prioritize what enforcement actions they carry out, given the fact that the number of resources is limited. These resources compete with carrying out new inspections in facilities where there is no information on their compliance (for instance, several facilities in the sector of Fishing-Aquaculture). An alternative to this current strategy may be to impose sanctions immediately once the violations have been found since our findings also show that receiving fines has a positive impact on the compliance of the violators and, we found spillover impacts on related facilities. With the same criteria, we can also speculate that for these fined facilities the investment for environmental compliance was done since we found a higher probability of compliance after the sanction.

Our study contains a description of the monitoring and enforcement actions of the SMA during its first years of operation and links all stages from inspection to payment of fines, adjusting for the selection bias of the inspection. However, we acknowledge that it does not provide causal estimates therefore our results should be interpreted as correlations. Our study may be extended in several ways. First, instead of focusing on sectors, we could extend the comparison of environmental compliance among different environmental instruments, beyond environmental permits. Second, is worth evaluating the deterrence effect of the SMA's monitoring and enforcement actions on the level of emissions (in air or water), instead of the analysis considering only a binary variable for compliance. This type of analysis may provide a better measure of the environmental damage avoided by the actions of the SMA. Finally, another interesting analysis to pursue could focus on a specific sector adding information about the production processes (such as production cycles in aquaculture) or about the abatement costs (such as the investments in filters or in electrostatic precipitators for power plants). By including such detailed information on the analysis of the SMA, the regulator might improve the decision about which facilities to inspect and when that needs to be done. This type of information could be useful for the design of enforcement strategies under limited budget and resources.

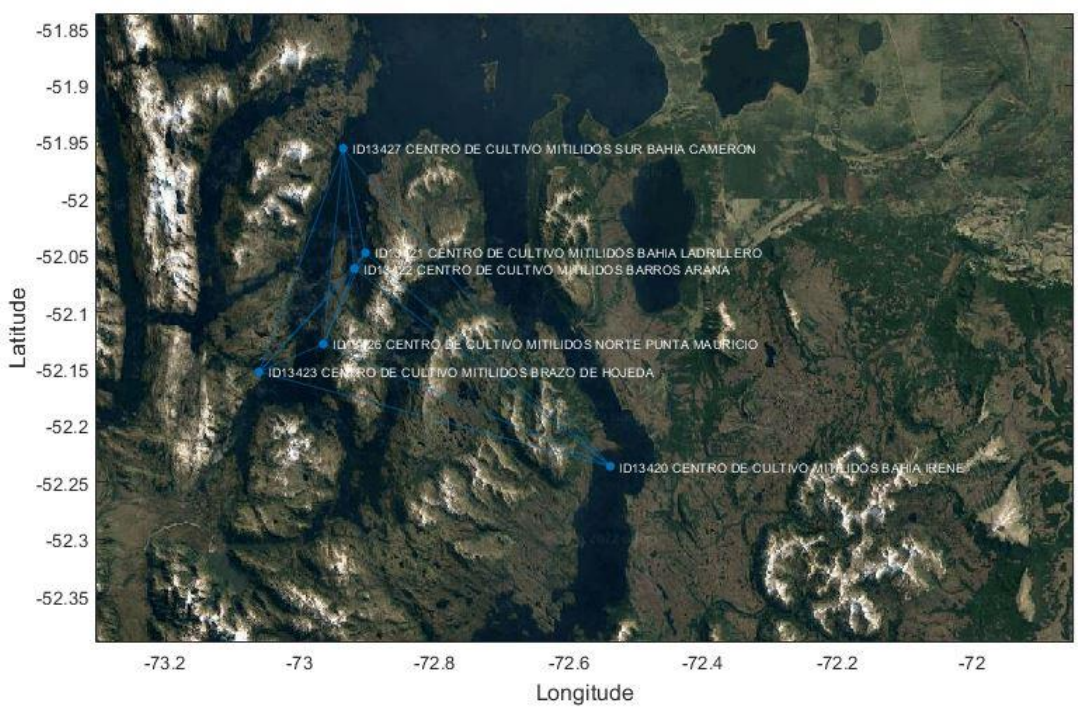
APPENDICES

Appendix 1. Different Networks Connecting Facilities with Same Owner



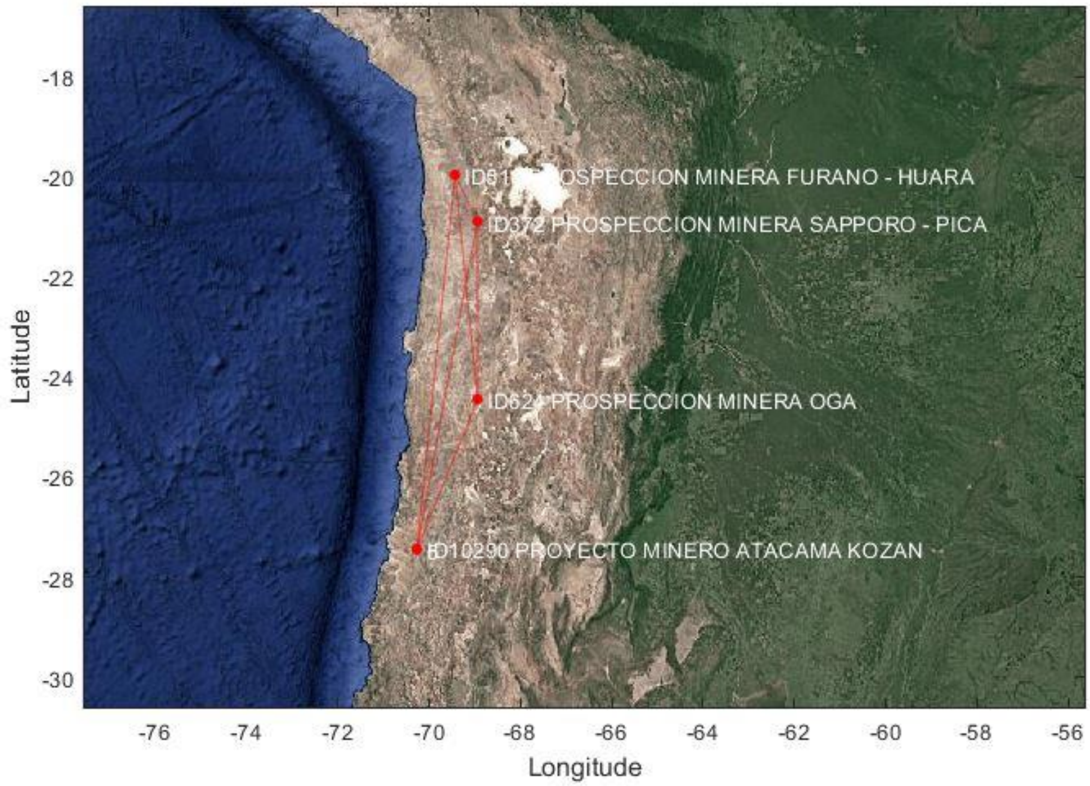
Source: Own elaboration based on information from SNIFA.

Appendix 2. Cluster (N465) Belonging to Fishing-Aquaculture Sector



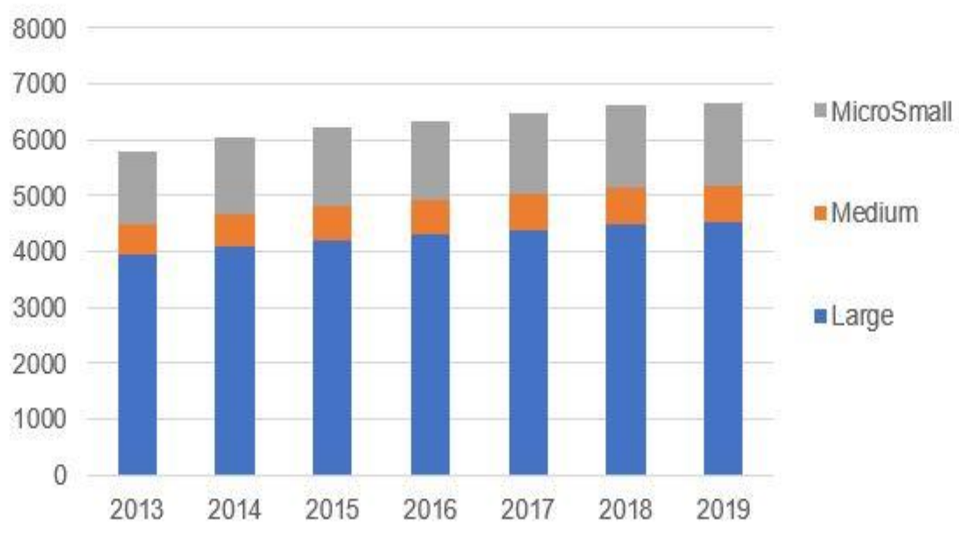
Source: Own elaboration based on information from SNIFA.

Appendix 3. Cluster (N56) Belonging to Mining Sector



Source: Own elaboration based on information from SNIFA.

Appendix 4. Number of Facilities by Size from 2013 to 2019

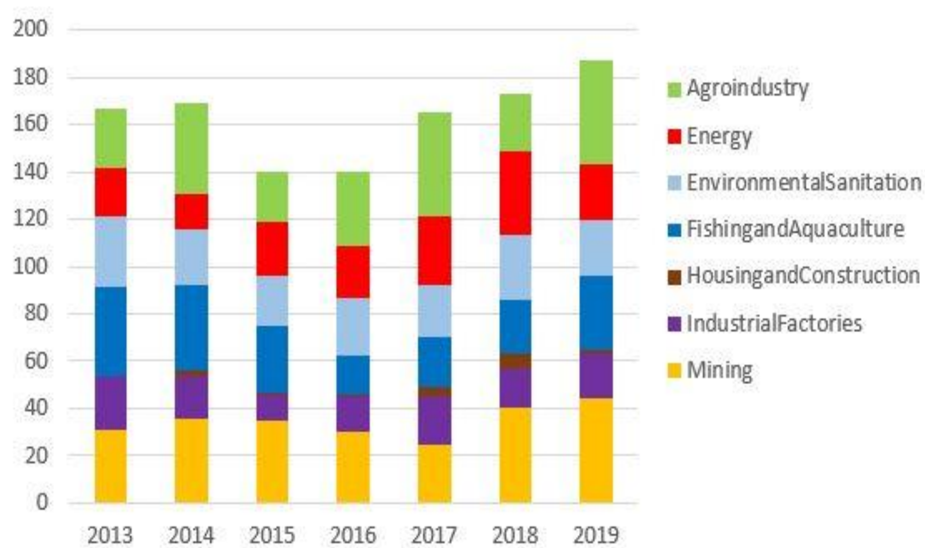


Source: Own elaboration based on information from SNIFA.

Appendix 5. Number of Facilities by Macrozone from 2013 to 2019

Source: Own elaboration based on information from SNIFA.

Appendix 6. Number of Facilities Inspected per Year

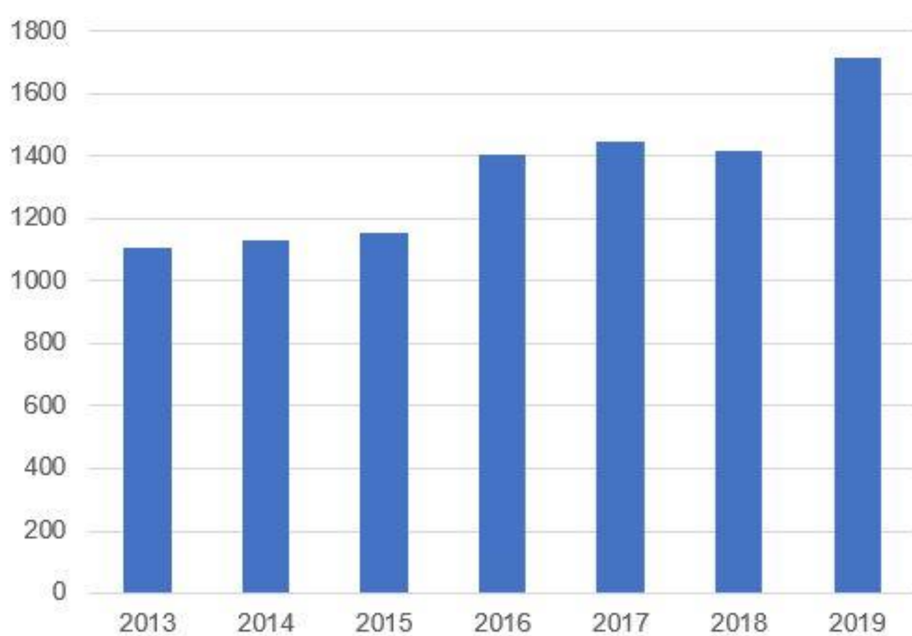


Source: Own elaboration based on information from SNIFA.
Note: We count the number of facilities that faced at least 1 inspection by sector in time from 2013 to 2019

Appendix 7. Number of Inspectors and Workers at SMA from 2013 to 2019

Source: Own elaboration based on information from SNIFA.

Appendix 8. Budget SMA in Millions of Nominal Pesos ($Ch)



Source: Own elaboration based on information from SNIFA.

Appendix 9. Average Marginal Effects for Inspection and Comply

VARIABLES	Average Marginal Effects. (Pr(Insp.=1)	Average Marginal Effects. Pr(Comp.=1, Insp.=1)
Sectors (base: Fishing-Aqu.)		
Agroindustry	0.0233***	0.0151***
	(0.00469)	(0.00365)
Energy	0.0155***	0.0122***
	(0.00442)	(0.00364)
Environmental Sanitation	0.0151***	0.00667***
	(0.00416)	(0.00242)
Housing-Construction	-0.00677***	-0.00561***
	(0.00262)	(0.00141)
Mining	0.0161***	0.0106***
	(0.00476)	(0.00318)
Industrial Factories	0.0164***	0.0116***
	(0.00505)	(0.00353)
Age	-0.00072***	-0.000374**
	(0.000199)	(0.000151)
Size (base: Medium)		
Micro and Small	-0.00717**	-0.00316
	(0.00312)	(0.00231)
Large	-0.00861***	-0.00321
	(0.00290)	(0.00214)
LogPoverty	0.00320	0.00192
	(0.00211)	(0.00148)
LogDensity	0.000205	0.000599
	(0.000595)	(0.000412)
Inspection_lastyear	0.0189***	0.0142***
	(0.00361)	(0.00248)
Report_lastyear	0.0124***	0.0134***
	(0.00297)	(0.00223)
AnyViolation_last3years	0.0168***	-0.00128
	(0.00348)	(0.00241)
Fined_last3years	0.0211***	0.0134**
	(0.00795)	(0.00551)
Compliance Program	0.0305***	0.00333
	(0.00332)	(0.00206)
Prioritized Area	0.00375***	0.000410
	(0.00145)	(0.000344)
Macrozone (base: SUR)		
NGR	0.0122*	0.0141***
	(0.00722)	(0.00498)
NCH	0.00698	0.00593*
	(0.00533)	(0.00329)
CEN	-0.000466	-0.00177
	(0.00378)	(0.00262)
CES	0.00163	0.00114
	(0.00344)	(0.00252)
Num. Instruments	0.00336***	0.00158***
	(0.000657)	(0.000342)
logSMABudgetperFacility	0.00176	0.000192
	(0.00316)	(0.000406)
logNumFacilitiesRegion	1.59e-05	1.73e-06
	(0.00288)	(0.000314)

Standard errors clustered by networks of facilities with common owners; *** p<0.01, ** p<0.05, * p<0.1

Appendix 10. Spillover Average Marginal Effect on Compliance

	Spillover RUT		Spillover Network		Spillover Sector		Spillover Comunne		Spillover SectorComunne	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	Comp	Insp	Comp	Insp	Comp	Insp	Comp	Insp	Comp	Insp
Agroindustry	0.455***	0.466***	0.449***	0.465***	0.448***	0.464***	0.451***	0.465***	0.453***	0.465***
	(0.0950)	(0.0839)	(0.0975)	(0.0839)	(0.0954)	(0.0845)	(0.0953)	(0.0838)	(0.0968)	(0.0835)
Energy	0.403***	0.347***	0.404***	0.347***	0.406***	0.346***	0.404***	0.346***	0.415***	0.345***
	(0.106)	(0.0875)	(0.107)	(0.0877)	(0.107)	(0.0882)	(0.105)	(0.0876)	(0.108)	(0.0871)
Env.Sanitation	0.246***	0.341***	0.242***	0.340***	0.242***	0.339***	0.242***	0.340***	0.256***	0.338***
	(0.0862)	(0.0855)	(0.0887)	(0.0855)	(0.0867)	(0.0860)	(0.0865)	(0.0855)	(0.0870)	(0.0851)
Housing-Construction	-0.478***	-0.277**	-0.485***	-0.278**	-0.401**	-0.279**	-0.484***	-0.279**	-0.391**	-0.279**
	(0.155)	(0.119)	(0.156)	(0.119)	(0.173)	(0.119)	(0.155)	(0.119)	(0.175)	(0.118)
Mining	0.354***	0.358***	0.356***	0.357***	0.367***	0.356***	0.358***	0.356***	0.380***	0.355***
	(0.0940)	(0.0947)	(0.0969)	(0.0945)	(0.0951)	(0.0953)	(0.0933)	(0.0947)	(0.0933)	(0.0941)
Industrial Factories	0.380***	0.363***	0.381***	0.363***	0.378***	0.362***	0.381***	0.362***	0.393***	0.361***
	(0.100)	(0.0975)	(0.101)	(0.0973)	(0.100)	(0.0977)	(0.100)	(0.0976)	(0.101)	(0.0971)
Age	-0.0111**	-0.0149***	-0.0112**	-0.0149***	-0.0113**	-0.0149***	-0.0112**	-0.0149***	-0.0118**	-0.0149***
	(0.00502)	(0.00418)	(0.00502)	(0.00418)	(0.00505)	(0.00418)	(0.00501)	(0.00417)	(0.00503)	(0.00417)
Micro and Small	-0.0844	-0.132**	-0.0882	-0.132**	-0.0875	-0.132**	-0.0898	-0.132**	-0.0827	-0.133**
	(0.0716)	(0.0551)	(0.0694)	(0.0552)	(0.0696)	(0.0552)	(0.0695)	(0.0552)	(0.0685)	(0.0553)
Large	-0.0775	-0.162***	-0.0843	-0.162***	-0.0848	-0.162***	-0.0861	-0.162***	-0.0807	-0.164***
	(0.0618)	(0.0497)	(0.0611)	(0.0499)	(0.0614)	(0.0499)	(0.0615)	(0.0498)	(0.0619)	(0.0497)
logPercentagePovertyCity	0.0582	0.0667	0.0594	0.0664	0.0574	0.0666	0.0595	0.0664	0.0557	0.0670
	(0.0490)	(0.0445)	(0.0485)	(0.0442)	(0.0515)	(0.0442)	(0.0482)	(0.0444)	(0.0490)	(0.0443)
LogDensity	0.0218	0.00416	0.0219	0.00426	0.0221	0.00451	0.0217	0.00427	0.0211	0.00435
	(0.0138)	(0.0124)	(0.0139)	(0.0124)	(0.0143)	(0.0124)	(0.0138)	(0.0124)	(0.0144)	(0.0125)
Inspection_lastyear	0.458***	0.393***	0.459***	0.393***	0.464***	0.392***	0.459***	0.393***	0.456***	0.394***
	(0.0780)	(0.0743)	(0.0772)	(0.0745)	(0.0791)	(0.0745)	(0.0776)	(0.0744)	(0.0801)	(0.0742)
Report_lastyear	0.455***	0.258***	0.457***	0.257***	0.454***	0.257***	0.458***	0.256***	0.461***	0.254***
	(0.0792)	(0.0613)	(0.0801)	(0.0615)	(0.0825)	(0.0615)	(0.0779)	(0.0614)	(0.0762)	(0.0613)
AnyViolation_last3years	-0.123	0.351***	-0.118	0.350***	-0.122	0.350***	-0.118	0.350***	-0.118	0.351***
	(0.0787)	(0.0718)	(0.0784)	(0.0720)	(0.0802)	(0.0721)	(0.0772)	(0.0720)	(0.0765)	(0.0719)
Fined_3y	0.408**	0.434***	0.420**	0.438***	0.417**	0.437***	0.425**	0.437***	0.429**	0.433***
	(0.176)	(0.162)	(0.177)	(0.163)	(0.178)	(0.164)	(0.175)	(0.163)	(0.176)	(0.163)
PDCactiv		0.633***		0.634***		0.634***		0.633***		0.632***
		(0.0664)		(0.0666)		(0.0667)		(0.0666)		(0.0665)
PrioritizedArea		0.0750**		0.0780***		0.0784**		0.0762***		0.0799***
		(0.0300)		(0.0303)		(0.0307)		(0.0291)		(0.0286)
logSMABudgetperFacilit yRE		0.0343		0.0365		0.0424		0.0390		0.0582
		(0.0640)		(0.0667)		(0.0687)		(0.0648)		(0.0620)
logNumFacilitiesRegion		0.000639		0.000381		0.00359		0.00366		0.0214
		(0.0595)		(0.0604)		(0.0602)		(0.0595)		(0.0609)
o.logBudgetRE		-		-		-		-		-
Nins	0.0454***	0.0698***	0.0460***	0.0698***	0.0463***	0.0697***	0.0458***	0.0699***	0.0459***	0.0699***
	(0.0101)	(0.0136)	(0.0102)	(0.0136)	(0.0102)	(0.0136)	(0.0101)	(0.0136)	(0.0101)	(0.0136)
AnyFine_SameOwner3y	0.222**									
	(0.0896)									
AnyFine_SameNet3y			-0.000400							
			(0.0559)							
AnyFine_Sector3y					0.0855				0.0834	
					(0.0813)				(0.0816)	
AnyFine_Comune3y							-0.0226		-0.0658	
							(0.0326)		(0.0410)	
AnyFine_SectorCom3y									0.128**	
									(0.0559)	
Constant	-2.565***	-2.203***	-2.563***	-2.196***	-2.632***	-2.203***	-2.558***	-2.211***	-2.618***	-2.282***
	(0.160)	(0.364)	(0.162)	(0.358)	(0.178)	(0.364)	(0.160)	(0.360)	(0.180)	(0.369)
Year Fixed Effect	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Macrozone Fixed Effect	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	37,425	37,425	37,425	37,425	37,425	37,425	37,425	37,425	37,425	37,425

Note: Standard errors clustered by Networks of facilities with common owners. *** p<0.01, ** p<0.05, * p<0.1

Appendix 11. Comparison Among Coefficient Estimates with Spillover Effects

	Original model		Model with RUT spillover		Model with Network spillover	
VARIABLES	(1) Inspection	(2) Comply	(3) Inspection	(4) Comply	(5) Inspection	(6) Comply
Agroindustry	0.465***	0.449***	0.467***	0.454***	0.466***	0.447***
	(0.0842)	(0.0952)	(0.0850)	(0.0938)	(0.0857)	(0.0967)
Energy	0.347***	0.404***	0.348***	0.402***	0.348***	0.398***
	(0.0879)	(0.106)	(0.0881)	(0.106)	(0.0888)	(0.109)
Env. Sanitation	0.340***	0.242***	0.342***	0.243***	0.341***	0.237***
	(0.0857)	(0.0864)	(0.0861)	(0.0862)	(0.0865)	(0.0885)
Housing-Construction	-0.278**	-0.485***	-0.277**	-0.477***	-0.277**	-0.481***
	(0.119)	(0.155)	(0.119)	(0.157)	(0.119)	(0.161)
Mining	0.357***	0.356***	0.359***	0.351***	0.359***	0.350***
	(0.0949)	(0.0940)	(0.0958)	(0.0938)	(0.0958)	(0.0988)
Industrial Factories	0.363***	0.381***	0.364***	0.378***	0.363***	0.379***
	(0.0977)	(0.0999)	(0.0978)	(0.100)	(0.0975)	(0.101)
Age	-0.0149***	-0.0112**	-0.0149***	-0.0109**	-0.0149***	-0.0111**
	(0.00418)	(0.00502)	(0.00419)	(0.00498)	(0.00419)	(0.00505)
Micro and Small	-0.132**	-0.0882	-0.131**	-0.0862	-0.131**	-0.0922
	(0.0552)	(0.0694)	(0.0549)	(0.0759)	(0.0551)	(0.0748)
Large	-0.162***	-0.0843	-0.162***	-0.0774	-0.162***	-0.0858
	(0.0498)	(0.0613)	(0.0497)	(0.0627)	(0.0499)	(0.0619)
LogPoverty	0.0664	0.0594	0.0666	0.0602	0.0661	0.0633
	(0.0444)	(0.0490)	(0.0442)	(0.0537)	(0.0442)	(0.0547)
LogDensity	0.00426	0.0219	0.00387	0.0215	0.00395	0.0211
	(0.0124)	(0.0139)	(0.0124)	(0.0137)	(0.0124)	(0.0143)
Inspection_lastyear	0.393***	0.459***	0.392***	0.459***	0.393***	0.458***
	(0.0744)	(0.0778)	(0.0745)	(0.0769)	(0.0745)	(0.0767)
Report_lastyear	0.257***	0.457***	0.259***	0.454***	0.258***	0.453***
	(0.0614)	(0.0800)	(0.0615)	(0.0823)	(0.0618)	(0.0856)
AnyViolation_last3years	0.350***	-0.118	0.351***	-0.122	0.350***	-0.116
	(0.0720)	(0.0782)	(0.0718)	(0.0800)	(0.0720)	(0.0789)
Fined_last3years	0.438***	0.420**	0.433***	0.404**	0.440***	0.413**
	(0.163)	(0.176)	(0.162)	(0.174)	(0.164)	(0.177)
Compliance Program	0.634***		0.634***		0.634***	
	(0.0666)		(0.0664)		(0.0666)	
Prioritized Area	0.0780***		0.0759**		0.0778**	
	(0.0298)		(0.0318)		(0.0331)	
NGR	0.223*	0.405***	0.230*	0.398***	0.227*	0.400***
	(0.123)	(0.100)	(0.126)	(0.100)	(0.130)	(0.102)
NCH	0.138	0.182*	0.143	0.183*	0.141	0.184*
	(0.103)	(0.0937)	(0.105)	(0.0950)	(0.108)	(0.0965)
CEN	-0.0105	-0.0738	-0.00965	-0.0751	-0.00880	-0.0690
	(0.0852)	(0.105)	(0.0850)	(0.107)	(0.0854)	(0.111)
CES	0.0353	0.0391	0.0374	0.0388	0.0374	0.0417
	(0.0746)	(0.0893)	(0.0753)	(0.0900)	(0.0762)	(0.0937)
logSMABudgetperFacility	0.0365		0.0357		0.0352	
	(0.0655)		(0.0647)		(0.0670)	
logNumFacilitiesRegion	0.000329		0.00398		0.00225	
	(0.0598)		(0.0598)		(0.0627)	
Num. Instruments	0.0698***	0.0460***	0.0698***	0.0454***	0.0698***	0.0461***
	(0.0136)	(0.0101)	(0.0136)	(0.0101)	(0.0136)	(0.0103)
Athrho	3.419***	3.419***	3.569**	3.569**	3.569*	3.569*
	(0.985)	(0.985)	(1.447)	(1.447)	(1.838)	(1.838)
Inspection_l3years_S_RUT				0.0210		
				(0.0459)		
AnyViolation_l3years_S_RUT				-0.0356		
				(0.0449)		
Fined_l3years_RUT				0.232**		
				(0.101)		
Inspection_l3years_S_Network						0.0319
						(0.0549)
AnyViolation_l3years_S_Network						-0.0390
						(0.0561)
Fined_l3years_S_Network						0.00523
						(0.0582)
Constant	-2.196***	-2.563***	-2.221***	-2.572***	-2.211***	-2.568***
	(0.366)	(0.160)	(0.377)	(0.168)	(0.391)	(0.174)
Observations	37,425	37,425	37,425	37,425	37,425	37,425

Standard errors clustered by Networks of facilities with common owners. *** p<0.01, ** p<0.05, * p<0.1

Appendix 12. Average Marginal Effects for Compliance Program

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Sectors (base: Fishing-Aqua.)						
Agroindustry	-0.0876	0.0255	-0.0335	-0.0883	0.0339	-0.0249
	(0.0921)	(0.0857)	(0.100)	(0.0916)	(0.0869)	(0.0991)
Energy	0.0857	0.0710	0.133	0.0841	0.0580	0.133
	(0.0931)	(0.105)	(0.101)	(0.0938)	(0.112)	(0.104)
Environmental Sanitation	0.0848	0.0886	0.146	0.0886	0.0840	0.169**
	(0.0790)	(0.0902)	(0.0911)	(0.0759)	(0.0909)	(0.0860)
Mining	-0.0794	-0.134	-0.0627	-0.0650	-0.0839	-0.0246
	(0.111)	(0.106)	(0.124)	(0.113)	(0.110)	(0.124)
Industrial Factories	-0.115	-0.0451	-0.0586	-0.100	-0.0147	-0.0190
	(0.112)	(0.103)	(0.115)	(0.109)	(0.103)	(0.110)
Size (base: Medium)						
Micro and Small	-0.372***	-0.335***	-0.357***	-0.346***	-0.324***	-0.322***
	(0.112)	(0.101)	(0.113)	(0.112)	(0.0986)	(0.110)
Large	-0.00908	0.0577	0.00962	-0.00934	0.0569	0.0160
	(0.0560)	(0.0518)	(0.0585)	(0.0577)	(0.0519)	(0.0618)
Macrozone (base: SUR)						
NGR	0.00140	0.0923	0.0734	-0.0171	0.0810	0.0640
	(0.0754)	(0.0612)	(0.0679)	(0.0781)	(0.0582)	(0.0677)
NCH	0.0483	0.0941	0.0881	0.0494	0.0845	0.0979
	(0.0707)	(0.0627)	(0.0676)	(0.0677)	(0.0609)	(0.0605)
CEN	-0.122	-0.118	-0.124	-0.134	-0.133	-0.131
	(0.104)	(0.103)	(0.111)	(0.104)	(0.102)	(0.110)
CES	-0.289***	-0.217**	-0.274**	-0.295***	-0.229**	-0.301***
	(0.109)	(0.110)	(0.119)	(0.106)	(0.110)	(0.116)
Age	-0.00161	-0.00301	-0.00190	0.000163	-0.00275	-4.54e-05
	(0.00601)	(0.00579)	(0.00625)	(0.00641)	(0.00605)	(0.00632)
LogPoverty	0.109*	0.0984*	0.100	0.119*	0.108*	0.121*
	(0.0595)	(0.0565)	(0.0638)	(0.0614)	(0.0571)	(0.0668)
LogDensity	0.0161	0.0247	0.0147	0.0151	0.0225	0.0110
	(0.0177)	(0.0159)	(0.0181)	(0.0170)	(0.0154)	(0.0169)
ImpactIndex	0.00255	0.00281	0.00383			
	(0.00479)	(0.00422)	(0.00472)			
Num_Infractions				0.00529	0.00260	0.00451
				(0.00715)	(0.00605)	(0.00655)
LowInfraction				-0.0428	0.0140	-0.00483
				(0.101)	(0.0927)	(0.110)
MiddleInfraction				-0.0482	-0.0456	-0.0455
				(0.0648)	(0.0684)	(0.0675)
HighInfraction				0.150*	0.220***	0.346***
				(0.0897)	(0.0797)	(0.121)
Relapse	-0.233***	-0.127*	-0.218***	-0.235***	-0.116*	-0.230***
	(0.0686)	(0.0688)	(0.0717)	(0.0661)	(0.0677)	(0.0696)
Complaint	-0.0376	-0.0104	-0.0215	-0.0457	-0.00662	-0.0307
	(0.0618)	(0.0560)	(0.0636)	(0.0633)	(0.0577)	(0.0654)
Num. instruments	-0.00627	-0.00118	-0.00120	-0.00651	-0.00120	-0.00303
	(0.00796)	(0.00777)	(0.00968)	(0.00791)	(0.00777)	(0.00963)
IMR		-2.769***			-2.902***	
		(0.533)			(0.537)	
PNONCOMP			-1.038			-1.114*
			(0.649)			(0.655)
Observations	193	192	184	193	192	184

Source: Own elaboration based on information from SNIFA.
Note: Standard errors clustered by facilities ownership in parentheses *** p<0.01, ** p<0.05, * p<0.1

Appendix 13. Estimates and Average Marginal Effects for Payment of Fines

VARIABLES	(1) Fine paid in 1 year or less	(2) Average marginal effect	(3) Fine paid in 2 year or less	(4) Average marginal effect	(5) Fine paid in 3 year or less	(6) Average marginal effect
Fine_1000USD	-2.22e-06	-5.96e-07	3.63e-05	9.58e-06	0.000138	3.21e-05
	(0.000109)	(2.91e-05)	(0.000148)	(3.92e-05)	(0.000234)	(5.38e-05)
Sectors (base: Fishing & Aqu.)						
Agroindustry	-0.167	-0.0507	0.00338	0.000947	0.626	0.138
	(0.576)	(0.174)	(0.612)	(0.171)	(0.665)	(0.147)
Energy	0.354	0.0995	0.0537	0.0149		
	(0.908)	(0.247)	(0.964)	(0.267)		
Environmental Sanitation	-0.583	-0.180	-0.659	-0.193	-0.877	-0.206
	(0.630)	(0.191)	(0.666)	(0.193)	(0.691)	(0.160)
Housing and Construction	-	-	-	-	-	-
Mining	-0.235	-0.0717	-0.0485	-0.0137	-0.311	-0.0745
	(0.714)	(0.214)	(0.793)	(0.223)	(0.933)	(0.220)
Industrial Factories	1.161	0.265	0.837	0.198	0.420	0.0956
	(0.772)	(0.171)	(0.832)	(0.191)	(0.909)	(0.205)
Large	1.144**	0.307***	0.832*	0.220*	1.071*	0.248*
	(0.456)	(0.102)	(0.505)	(0.120)	(0.625)	(0.127)
Macrozone (base: SUR)						
NGR	-0.747	-0.203	-1.384	-0.354	-1.766*	-0.381
	(0.806)	(0.226)	(0.899)	(0.248)	(1.046)	(0.233)
NCH	-0.143	-0.0359				
	(0.637)	(0.160)				
CEN	-0.176	-0.0445	-0.947	-0.226*	-1.198	-0.237*
	(0.574)	(0.142)	(0.626)	(0.131)	(0.764)	(0.123)
CES	-1.025*	-0.283**	-1.394**	-0.356***	-1.510**	-0.316***
	(0.563)	(0.135)	(0.623)	(0.127)	(0.729)	(0.113)
Age	-0.0904*	-0.0243*	-0.0268	-0.00707	0.0253	0.00586
	(0.0496)	(0.0126)	(0.0510)	(0.0133)	(0.0517)	(0.0120)
Relapse	0.0270	0.00725	0.281	0.0742	0.131	0.0303
	(0.413)	(0.111)	(0.462)	(0.122)	(0.581)	(0.135)
Complaint	0.241	0.0646	0.372	0.0982	0.904	0.210
	(0.414)	(0.110)	(0.434)	(0.112)	(0.609)	(0.129)
Num. Instruments	0.0420	0.0113	0.0880	0.0232	0.197**	0.0458**
	(0.0437)	(0.0117)	(0.0583)	(0.0156)	(0.0952)	(0.0219)
IMR	2.532	0.680	-0.357	-0.0942	0.744	0.172
	(2.699)	(0.725)	(3.132)	(0.826)	(3.325)	(0.775)
Constant	0.475		0.988		-0.761	
	(1.309)		(1.606)		(1.612)	
Observations	77	77	69	69	65	65

Standard errors clustered by facilities ownership in parentheses *** p<0.01, ** p<0.05, * p<0.1

Reference

Blackman, A. (2010). Alternative Pollution Control Policies in Developing Countries. *Review of Environmental Economics and Policy* 4(2): 234–53.

Blackman, A., Zhengyan L., Antung A. L. (2018). Efficacy of Command-and-Control and Market-Based Environmental Regulation in Developing Countries. *Annual Review of Resource Economics* 10: 381–404.

Briceño, S., Chávez C. (2010). Determinantes de Cumplimiento En El Programa de Tasas Retributivas En Colombia: Elcaso de Corpochivor. *Trimestre Economico* 77(308): 1007–36.

Caffera, M. (2004). Effectiveness of the Enforcement of Industrial Emission Standards in Montevideo, Uruguay. *Revista de Ciencias Empresariales y Economía* (3): 79–116.

Chakraborti, L. (2022). Environmental deterrence in developing countries: evidence from enforcement actions and fines under the toxics monitoring program of Mexico. *Environment and Development Economics*, 1-22.

Chávez, C. A., Stranlund, J. K., Gómez, W. (2011). Controlling urban air pollution caused by households: Uncertainty, prices, and income. *Journal of Environmental Management*.

Cohen MA. (1987). Optimal Enforcement Strategy to Prevent Oil Spills: An Application of a Principal-Agent Model with Moral Hazard. *J. Law Econ*. 30:23–51

Dasgupta S, Laplante B, Mamingi N, Wang H. (2001). Inspections, Pollution Prices, and Environmental Performance: Evidence from China. Ecol. Econ. 36:487–98

Earnhart D. (2004). Regulatory Factors Shaping Environmental Performance at Publicly-owned Treatment Plants. *J. Environ. Econ. Manag*. 48:655–81

Earnhart, D. (2009). The Influence of Facility Characteristics and Permit Conditions on the Effectiveness of Environmental Regulatory Deterrence. *Journal of Regulatory Economics* 36(3): 247–73.

Eckert H, Eckert A. (2010). The Geographic Distribution of Environmental Inspections. *J. Regul. Econ*. 37:1–22

Escobar, N. Chávez C. (2013). Monitoring, Firms' Compliance and Imposition of Fines: Evidence from the Federal Industrial Inspection Program in Mexico City. *Environment and Development Economics* 18(6): 723–48.

Jeuland, M., Fetter, T. R., Li, Y., Pattanayak, S. K., Usmani, F., Bluffstone, R. A., Chávez, C., Girardeau, H., Hassen, S., Jagger, P., Jaime, M. M., Karumba, M., Köhlin, G., Lenz, L., Litzow, E. L., Masatsugu, L., Naranjo, M. A., Peters, J., Qin, P., … Toman, M. (2021). Is energy the golden thread? A systematic review of the impacts of modern and traditional energy use in low- and middle-income countries. In *Renewable and Sustainable Energy Reviews* (Vol. 135, p. 110406). Elsevier Ltd.

Laplante, B., Rilstone P. (1996). Environmental Inspections and Emissions of the Pulp and Paper Industry in Quebec. *Journal of Environmental Economics and Management* 31(1): 19–36.

Meng, C., Schmidt P. (1985). On the Cost of Partial Observability in the Bivariate Probit Model. *International Economic Review* 26(1).

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

Poirier, D. J. (1980). Partial Observability in Bivariate Probit Models. *Journal of Econometrics* 12(2).

Rousseau, S. (2009). Empirical Analysis of Sanctions for Environmental Offenses. *International Review of Environmental and Resource Economics*.

Shimshack, J. P. (2014). The Economics of Environmental Monitoring and Enforcement. *Annual Review of Resource Economics* 6(1): 339–60.

Shimshack, J. P., Ward M.B. (2005). Regulator Reputation, Enforcement, and Environmental Compliance. *Journal of Environmental Economics and Management*.

SMA. (2018). Superintendencia del Medio Ambiente Chile *Memoria de Gestion 2014-2018 Superintendencia Del Medio Ambiente Chile*.

Stranlund, J. K. (2013). Enforcement. In *Encyclopedia of Energy, Natural Resource, and Environmental Economics*, Elsevier Inc., 150–54.

US Agency Environmental Protection. (2020). *Superfund Compliance and Penalties*. https://www.epa.gov/enforcement/superfund-compliance-and-penalties

Ward, T., Noonan, C. (2008). Results of a Residential Indoor PM2.5 Sampling Program before and after a Woodstove Changeout. *Indoor Air* 18 (5): 408–15.

Wassie, Y. Adaramola, M. (2021). Analysis of Potential Fuel Savings, Economic and Environmental Effects of Improved Biomass Cookstoves in Rural Ethiopia. *Journal of Cleaner Production* 280.