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Abstract Using a series of laboratory economic experiments, we study the effect of information regarding the amount of the fine on the individual decision to violate an emission standard. Specifically, the analysis considers variations in the information available for the regulated subjects regarding the amount of the monetary sanction, as well as variations in the stringency in the inspection effort by the regulator. Our results suggest that in the case of a regulation design that induces compliance, the presence of uncertainty regarding the amount of the fine may increase violations in certain cases. When enforcement is not sufficient to induce compliance, the uncertainty regarding the amount of the fine does not have any effect on the level of transgression. Overall, the results suggest that a cost-effective regulation design should consider including public information on the consequences of an offense.

Keywords Uncertainty · Risk · Compound risk · Fine · Emission standard · Economic experiment

JEL Classification C91 · L51 · Q58 · K42

1. Introduction

Enforcement to induce compliance is a key element of the regulatory process. In the conventional model of enforcement (Becker, 1968), the regulated entity is an expected profit maximizer who, when deciding whether to comply with a norm, compares the marginal costs of complying with the marginal expected benefits of not complying. In this model, the regulator has two instruments to induce deterrence, the inspections (to detect violations) and the fines (to sanction discovered violations). In this conventional model, the regulated population responds to the regulator's choice of the intensity of monitoring as well as the level (and perhaps the structure) of the penalty to be levied in the event of a detected violation when having perfect information on the probability of being inspected and the structure and the amount of the monetary penalty to be paid in the event of being detected (Stranlund and Chávez 2002). However, actual penalties in the real world are not always certain. For example, in the Emissions Compensation Program of Santiago, Chile, the consequences of being found out of compliance vary between a written warning, a monetary penalty, or a temporary closure. At the same time, the amount of the monetary penalties may fluctuate over a wide range, with the amount finally imposed on an offender depending on specific characteristics of the offense, the amount of excess emissions, the severity of the offense, and other circumstances (Palacios and Chávez 2002). In Uruguay, Decree 253/79, which contains guidelines for water pollution control, imposes sanctions that vary according to the type of offense and its recurrence. The types of offenses are determined by the determined causes behind the discovered illegal level of pollution: not having a treatment plant, not operating the treatment plant correctly, etc. The size of the violation, that is, the difference between the level of actual pollution and the maximum level allowed, is not an explicit factor affecting the level of the fine. Moreover, the type of offense and the recurrence do not define a given level of a fine, but rather define the range, while the actual fine within this range is left to the discretion of the inspector. A further example is provided by Escobar and Chávez (2013) with respect to Mexico. In the event of detection of noncompliance with environmental regulations on emission discharges from companies operating in Mexico City, the authors note that, according to the current environmental legislation, the amount of the fine that may be imposed by the responsible regulatory agency should consider several criteria, including the severity of the offense, financial situation of the offender, intention and negligence, and profits made by the offender due to the violation, among others. Taken together, these examples suggest that the consequences of committing an offense if detected are far from being completely known by the polluting sources when making the decision regarding their compliance status. The situation is not apparently characteristic only of developing countries. In the US for example, while under SO2 program EPA automatically sanctions any excess emissions above the level of permits holdings with a known and predetermined fixed amount of money per excess tone, under the RECLAIM program facilities detected violating their emissions permits may face a financial penalty which depends on several specific circumstances, including, extent of violation, reasons for exceedance, and even effort of the facility to correct its violation (Chávez et. al., 2002). More generally, it has been argued that "the legal system does not persistently pursues predictability in sanctioning" (Baker et al, 2003, p. 447).

How does this uncertainty in the amount of the penalties or the harsh in punishment affect compliance? The environmental enforcement literature has been built upon theoretical models that in almost all cases assume risk-neutrality on the part of the polluting firms. Under this assumption, an increase in the uncertainty regarding the amount of the fine associated with a given level of violation, or more formally an increase in risk in the form of a men preserving spread in the fine, has no effect on the firms' behaviors. The tax compliance literature provides an expected utility model in which a subject decides how much of their income to report, given that it is audited with a certain probability and fined in case of found under-reporting with a certain fine. In this model, the effect of an increase in risk in the fine on the amount of declared income depends on the risk preferences of the reporting subject. The subject will respond to an increase in risk in the fine with an increase in declared income if it exhibits non-decreasing absolute risk-aversion (Alm et al, 1992). On the other hand, Harel (1999) argues that criminals would prefer a scheme in which the degree of the sentence is uncertain. No such results have been produced in the environmental enforcement literature.

It is in the tax compliance and law and economics literature that we found the only cases of experimental tests of these behavioral hypotheses. Most of these works, nevertheless, investigates the effect of uncertainty in other enforcement parameters. De Angelo (2012) developed a framed laboratory experiment to investigate the effects of uncertainty in the probability of detection (maintaining the expected cost of a continuing violation) on compliance with a speed limit. The author finds that this measure results in a significant reduction in detected offenses. These results suggest that the inclusion of uncertainty may reduce the number of violations. In contrast to De Angelo's design, our analysis investigates the effect of uncertainty on the level of the fine for detected violations, not on the probability of being detected. In De Angelo's (2012) design, the fine imposed on detected violators is well known by the regulated population.

The only experimental investigations of the effect of the uncertainty in the fine on compliance behavior that we are aware of are Alm et. al. (1992) and Baker et. al. (2003). Using an income tax declaration framework, Alm et. al. (1992) find that an increase in measurable uncertainty (risk) in the fine increase compliance. Using a loose frame in which subjects choose between a lottery through which subjects could gain additional money but being fined if caught playing this lottery, Baker et al (2004) found that an increase in risk in the fine for playing the lottery decreases the percentage of subjects playing the lottery.

This is a rather surprisingly state of the literature given the importance of the matter. For example, if uncertain penalties increase compliance, uncertain penalties could increase the cost-effectiveness of enforcement regimes. Moreover, the literature does not distinguish between the mentioned effect in situations in which the enforcement regime induces perfect compliance and those in which there is noncompliance. Finally, we know nothing of this effect in other types of frameworks, such as in the case enforcement of emission standards.

In this paper, we analyze the effect of the certainty regarding the amount of the fine on the individual decision to violate an emissions standard, as well as differences in the stringency of the enforcement effort using a series of laboratory economic experiments. Our treatment variables are (a) the level of the inspection probability, and (b) the level of certainty in the amount of the fines for non/complying. With respect to the latter, more specifically we consider a first case where the amount of the fine due to noncompliance is known with certainty and two treatments where the amount of the fines is unknown. In the second case the amount of the fine is defined through a simple fifty-fifty lottery between a "high" and a "low" penalty. The expected value of the penalty is the same as in the certainty case. In the third case the amount of the fine is decided through a compound lottery, with the same expected value.

The designed and applied series of laboratory economic experiments enable us to study how the presence of uncertainty with respect to the amount of the fine influences the decision of transgression and, eventually, the level of individual violation.[1]Furthermore, the analysis considers, on the one hand, an

[1]Whenever we refer to uncertainty, we refer to the uncertainty that can be measured. We are aware of Knight's distinction between risk (measurable uncertainty) and uncertainty (not measurable uncertainty). However, it seems better to talk about fines of certain amounts versus fines of uncertain amounts, rather than fines of certain amounts versus fines of risky amounts to differentiate the treatments of our experiments.

enforcement regime that is capable of inducing perfect compliance by risk neutral individuals in theory, and on the other hand, a system enforcement regime that induces violations. This allows us to test whether there is a difference in the effect of the certainty regarding the amount of the fine.

Our results suggest that the information available on the consequences of being caught committing an offense may affect the decision regarding compliance. Specifically, in the case of a regulation design that induces compliance, we found evidence that the presence of uncertainty about the amount of the fine may increase violations in some cases. When the control system is not enough to induce compliance, the uncertainty about the amount of the fine has no effect on the level of transgression of the standard. Taken together, the results suggest that a cost-effective regulation design should provide perfect information concerning the consequences of a violation, since uncertain penalties would increase violations in a perfect enforcement regime, or they would have no effect on the level of violations in an imperfect enforcement regime.

The paper is organized as follows. In section 2, we present the main hypotheses to be evaluated with our experimental design, and in section 3, we describe the experimental design and procedures. Section 4 presents the results, and section 5 discusses the primary conclusions of the study.

2. Hypotheses

In this section, we present the main hypotheses evaluated using our laboratory experiment. These hypotheses are based on existing literature on compliance decisions of regulated firms operating under emission standards (Harford 1978; Stranlund 2013; Arguedas 2008; Caffera and Chávez 2011).

We consider an emissions standard system, which is controlled by a regulatory agency that conducts random inspections to detect violations and imposes fines that are conditional on detection. The analysis of individual behavior considers a risk neutral firm that operates under a system of emission standards with other heterogeneous firms. We index firms in I and denote the total number of regulated firms as n (when possible, for simplicity, we avoid the use of the index). Each firm is completely described by a function of abatement costs $c(q)$ that is strictly decreasing and convex in the level of emissions q $[c'(q) < 0 \; and \; c''(q) > 0]$. The environmental target is a fixed aggregate level of emissions, denoted as Q, which is exogenously determined by the regulatory authority.

Each firm faces an emission standard s. The standard represents the maximum level of emissions (legal) that the firm can discharge. The emissions standards for all firms meet $\sum_i s_i = Q$. In this context, a violation of the standard, denoted as v, occurs when the emissions level of the firm exceeds the standard,

$v = q - s > 0$. The firm is audited with an exogenously determined probability, π. An audit provides the regulator with perfect information about the status of the firm's compliance. If the firm is audited and found in violation of the standard, a penalty $f(v)$ is imposed. Following Stranlund (2007), the structure of the fine is given by $f\ (q - s) = \varphi(q - s) + (\gamma/2)(q - s)^2$, where $\varphi > 0$ and $\gamma > 0$.

Under the described regulatory scheme, and assuming that the fine is known with certainty, a firm selects the level of emission to minimize its expected compliance costs, which involves abatement costs plus the expected fine. The existing literature suggests that a risk neutral firm will choose to comply with the standard ($q = s$) if and only if $-c'(s) \leq \pi[\varphi + \gamma(q - s)]$ (Heyes 2000; Malik 1992; Harford 1978). That is, a firm will comply with the standard if the expected marginal penalty for an infringement is not less than the marginal cost of the abatement evaluated at the level of emission (the marginal benefit of the infringement). Otherwise, the firm will select a level of emission $q(s, \pi) > s$, where $q(s, \pi, \varphi, \gamma)$ is the solution to the equation $-c'(q) = \pi[\varphi + \gamma(q - s)]$

The regulator can choose a level of standard (s) more restrictive and at the same time reduce the probability of detection by applying, in this case, a system of standards with weak regulations, which induce violations, but in which the level of emissions both for individuals and for the aggregate remains constant.

In the event that the fine is uncertain, it is possible to show that, for the case in which the fine is imposed either by a lottery mechanism or a compound lottery mechanism and in which the expected value of the fine is equal to the known amount thereof, the compliance is not altered. Consequently, in the case of incomplete enforcement, the expected level of violation of the standard is the same as in the case of a known fine. [2]

Accordingly, the hypotheses to be evaluated herein are as follows.

Hypothesis 1: *In a system of emission standards under a regulation model that, theoretically, induces compliance, both the frequency and the level of violation of the standards are independent from the level of information about the fine (known fine, unknown fine with simple lottery and unknown fine with compound lottery whose expected value is equal to the known fine).*

Hypothesis 2: *In a system of emission standards under a regulation model that induces infringements, both the frequency and the level of violation of the standards are independent of the level of information*

[2]This result is available upon request from interested parties.

about the fine (known fine, uncertain fine with simple and compound lottery, whose value is equal to the known fine).

3. Experimental Design and procedure

In this section, we present the experimental design and the procedures followed to evaluate the hypotheses.

3.1. Design

We frame the experiment as a neutral production decision of an unspecified good. Individuals take the role of a producer of a fictitious good from which each of them receive benefits per unit produced.[3]The design of the treatments uses, as a reference, the experiment conducted by Caffera and Chávez (2013), which examines both tradable emissions permits and emissions standards. The units produced can take values from 1 to 10. The marginal benefits obtained from the production differ among individuals creating four types of subjects: two with “high” marginal benefits from production and two with “low” marginal benefits (see Table 1). These schedules of marginal benefits are the same through all the experiments and are randomly assigned across subjects. The level of production is regulated under a system based on standards. Compliance is controlled by a regulatory authority that conducts random inspections and imposes fines conditional on noncompliance detection.

[3]Cason (2011) evaluates whether the environmental framework influences the behavior of pollution control and the information in an experimental context. To do so, he presents a laboratory experiment that considers the environmental framework as a treatment variable in the context of a tradable emissions system with auto reporting of emissions and imperfect compliance. The results indicate that the volume of transactions and compliance rates were significantly lower with an environmental framework compared to neutral framework. This suggests that, under environmental framework, incentives from the subjects to honestly report on pollution issues to the regulator are reduced. Alm (1999) suggests that neutral terms conceal the context and the purpose of the experiment, which increases experimental control.

Table 1. Production marginal benefits of the fictitious good per type of firm

Produced Units	Production marginal benefits			
	Type 1	Type 2	Type 3	Type 4
1	161	151	129	125
2	145	134	113	105
3	130	119	98	88
4	116	106	84	74
5	103	95	73	63
6	91	86	63	54
7	80	79	53	47
8	70	74	44	42
9	61	70	35	38
10	53	67	27	35

Source: Cason and Gangadharan (2006).

The design of the experiment considers two regulatory schemes. The first is a strong control system (or complete enforcement) that induces compliance through a high inspection rate. The second is a weak control system (or incomplete enforcement), which allows violations of the standards by reducing the inspection rate but restricts the maximum allowable emissions levels.

We construct six different treatments for the experiment while varying the stringency of enforcement and the information available to subjects on the fine imposed for noncompliance. All treatments consider an increasing marginal penalty and differ in the degree of uncertainty regarding the amount of the fine to be imposed conditional on the detection of a transgression. Our interest is on evaluating the possible relevance to the individual behavior of the degree of information available to individuals regarding the consequences they face when detected violating the regulation.

The design considers uncertainty regarding the amount of the fine. First, a perfectly known fine is considered. In this case, each subject knows with certainty the fine to be imposed when found in noncompliance. Second, a fine in a simple lottery form is also considered. In this case, while the subjects do not know with certainty the fine that will be imposed, they do know that the amount of the fine may take a high value with a 50% probability or take a low value with 50% probability. Third, we consider a compound lottery fine. In this case, the subjects do not know with certainty the probability with which the amount of the fine can take different values. Specifically, the subjects face a 33% chance that the probability of being penalized with a low fine is zero (0), a 33% chancethat the probability of being penalized with a low fine is one-half (0.5), and chance 33% chance that the probability of being penalized with a low fine is one (1). A summary of the specifications of the treatments is presented in Table 2.

Table 2. Specifications per treatment

Treatment	Compliance	Fine
1	Perfect	Known
2	Perfect	With risk
3	Perfect	With compound risk
4	Violations	Known
5	Violations	With risk
6	Violations	With compound risk

Source: Authors

The values used for each parameter of the fine function, the probability of inspection, the maximum limit of allowed production, the aggregate standard, and the expected aggregated level of production are presented in Table 3.

The experiment has a between subjects design as the subjects participate in only one experimental session. As treatments are conducted in more than one session, it was considered reversing the order of application of the treatments to control for potential order effects.

3.2. Procedure

The experiments were implemented using z-tree (Fishbacher (2007)) software in the laboratories of the Center for Training and Learning Resources of the Universidad de Concepcion between June and August 2013.

Undergraduate student residents of Concepcion city were recruited from academic programs of commercial engineering, civil industrial engineering, and auditing at the following institutions: Universidad de Concepcion, Universidad Católica de la Santísima Concepción, and Universidad del Bio-Bio. The preferred participating student was a sophomores or above, thus ensuring they had basic knowledge and skills. In addition, subjects who had not previously participated in an experiment of this type were considered as their decision making was not conditioned.

In all, 225 students participated in the experiment, and 4,260 observations were obtained. However, 24 observations were voided because the participants experienced bankruptcy during the administration of one or both treatments. Bankruptcies were concentrated in those treatments with incomplete enforcement where individuals had an output above the level predicted by the theory.[4]

[4]Subjects who went bankrupt received the payments the same way as the rest of the participating subjects. For more details about the individuals who went bankrupt in each treatment, see Table A.1 in Annex 1.

Table 3.Parameters per treatment

Treatment	Probability of monitoring per type of firm				Probability per type of fine	Parameters value						Policy induces	Aggregated standards	Emissionsstandard	Expected aggregated level of emissions
						Fine		Low fine		High Fine					
	Type 1	Type 2	Type 3	Type 4		Phi	Gamma	Phi	Gamma	Phi	Gamma				
T1	0.6	0.65	0.63	0.66	1	100	66.67					Compliance	40	Type 1=7 Type 2=6 Type 3=4 Type 4=3	40
T2	0.6	0.65	0.63	0.66	0.5			50	33.37	150	99.9				
T3	0.6	0.65	0.63	0.66	0.33(1);0.33(0.5);0.33(0)			50	33.37	150	99.9				
T4	0.24	0.26	0.32	0.32	1	100	66.67					Violations	20	Type 1=4 Type 2=3 Type 3=2 Type 4=1	
T5	0.24	0.26	0.32	0.32	0.5			50	33.37	150	99.9				
T6	0.24	0.26	0.32	0.32	0.33(1);0.33(0.5);0.33(0)			50	33.37	150	99.9				

Source: Authors

The table shows the parameters considered in the penalty function $f(v^i) = \varphi(v^i) + (\gamma/2)(v^i)^2$ where $\varphi > 0$ and $\gamma > 0$. From this function, three types of fines arise that differ in the uncertainty degree. The first case is a known fine. In this case, each subject knows with certainty the fine to be imposed when caught in breach (T1 and T4). The second case is a fine in simple lottery form where the subjects do not know with certainty the fine that will be imposed. In this case, the subjects only know that the amount of the fine may take a high level with (0.5) probability and a low value with (0.5) probability (T2 and T4).The third case is a fine in compound lottery form where the subjects are unaware of the probability regarding the amount the fine may take with respect to the different values. In this case, the subjects face a chance of 33% that the probability of receiving a low fine is zero (0), a chance of 33% that the probability of receiving a low fine is one-half (0.5), and a chance of 33% that the probability of receiving a low fine is one (1).

The experiment consisted of six different treatments performed over nine experimental sessions[5]. In each experimental session, the subjects were exposed to two different treatments and a characterization survey. Each treatment had two test initial periods and ten valid periods.

At the beginning of each treatment, the subjects had an initial working capital of 1,050 experimental pesos. In addition, they were informed about the profits obtained per each unit produced in excess of the limit and the probability of inspection. In each period, the subjects had two minutes in which to make the production decision. After completing the ten periods, the final treatment results were informed before beginning the second treatment. Finally, at the end of the second treatment, the profits generated from both treatments were presented and the survey was administered.

After completion of the experimental session, earnings expressed in experimental pesos ($E) were converted into Chilean pesos ($Ch) at the change rate previously reported (two experimental pesos ($E 2) per one Chilean peso ($Ch)). Additionally, subjects received a payment of $2,000 Ch (approximately $4 US) for arriving on time, and they had the opportunityto make extra money if chosen for the lottery payment, a payment delivered to only one subject per session.

Instructions associated with each treatment were designed and then evaluated in a pilot study administered to students from the Master's Program in Economics of Natural Resources and Environment of the Universidad de Concepcion. As the pilot study determined that students had difficulty understanding the instructions, a set of slideshows was created to illustrate, as a summary, the instructions that were read at the beginning of each session/treatment. The set of slideshows used are available in Annex 2.

The experiment was designed to be administered to 32 subjects per session. With respect to the design of the experiment and the optimal size of the database, it is suggested that to obtain the effect of the treatment, the only necessary assumption is proper randomization (with proper samples size). The literature presents a remarkable consistency regarding sample size and layout, where most studies uniformly distribute at least 30 subjects in each cell (List 2010).

4. Results

The descriptive analysis presented in this subsection excludes from the sample those individuals who went bankrupt in the treatment in which they went bankrupt. That is, if one individual participated in treatments 1 and 2 and went bankrupt in the first treatment but not in the second, we discard their observations from treatment 1 and only use

[5]The detail of the treatments conducted in each session is presented in Table A.2 in Annex 1.

their observations from treatment 2. Additionally, over compliance is treated as a negative violation. It is further noted that we only consider the first eight periods of the ten valid periods per treatment.

4.1. Descriptive analysis

The descriptive analysis begins by studying the results obtained in the complete enforcement system, which induces compliance. We then review in detail the results obtained in the incomplete enforcement system, which induces violations.

Table 4 presents the descriptive statistics for the level of emissions and violations observed in the perfect enforcement treatments by type of firm. Modal behaviors are those predicted by theory. However, this is not the case with average behaviors. We note that the average violation is positive for all types of subjects in all perfect enforcement treatments. Average positive levels of violations in enforcement regimes that induce compliance in the margin have previously been observed in the literature (see, for example, Murphy and Stranlund (2006 and 2007) and Stranlund et al. (2011 and 2013) and Caffera and Chávez (2013). Our results, however, show that as an addition to the literature, this result does not depend on the level of certainty regarding the amount of the fines.

Table 4: Descriptive statistics forperfectenforcement experiments

Treatment 1		Type 1 (s=7)		Type 2 (s=6)		Type 3 (s=4)		Type 4 (s=3)	
		q	v	q	v	q	v	q	v
Theory		**7.00**	**0.00**	**6.00**	**0.00**	**4.00**	**0.00**	**3.00**	**0.00**
Known Fine	Mean	7.54	0.54	6.55	0.55	4.64	0.64	4.33	1.33
	Std. Dev.	0.99	0.99	1.01	1.01	1.13	1.13	1.34	1.34
	Mode	7.00	0.00	6.00	0.00	4.00	0.00	3.00	0.00
	Median	7.00	0.00	6.00	0.00	4.00	0.00	4.00	1.00
	# Obs.	160	160	176	176	168	168	144	144
Treatment 2		**Type 1 (s=7)**		**Type 2 (s=6)**		**Type 3 (s=4)**		**Type 4 (s=3)**	
		q	v	q	v	q	v	q	v
Theory		**7.00**	**0.00**	**6.00**	**0.00**	**4.00**	**0.00**	**3.00**	**0.00**
Fine in simple lottery form	Mean	7.41	0.41	7.11	1.11	4.85	0.85	4.00	1.00
	Std. Dev.	1.50	1.50	1.30	1.30	1.29	1.29	1.00	1.00
	Mode	7.00	0.00	6.00	0.00	4.00	0.00	3.00	0.00
	Median	7.00	0.00	7.00	1.00	4.00	0.00	4.00	1.00
	# Obs.	128	128	136	136	136	136	128	128
Treatment 3		**Type 1 (s=7)**		**Type 2 (s=6)**		**Type 3 (s=4)**		**Type 4 (s=3)**	
		q	v	q	v	q	v	q	v
Theory		**7.00**	**0.00**	**6.00**	**0.00**	**4.00**	**0.00**	**3.00**	**0.00**
Fine in compound lottery form	Mean	7.52	0.52	6.87	0.87	4.56	0.56	3.96	0.96
	Std. Dev.	1.14	1.14	1.33	1.33	0.85	0.85	1.08	1.08
	Mode	7.00	0.00	6.00	0.00	4.00	0.00	3.00	0.00
	Median	7.00	0.00	7.00	1.00	4.00	0.00	4.00	1.00
	# Obs.	128	128	136	136	136	136	128	128

Source: Authors.
The table shows the average, the standard deviation, the mode, the median, and the number of observations for (q) emissions and (v) violations.

Table 5: Descriptive statistics for imperfect-enforcement experiments

Treatment 4		Type 1 (s=4)		Type 2 (s=3)		Type 3 (s=2)		Type 4 (s=1)	
		q	v	q	v	q	v	q	v
Theory		**7**	**3**	**6**	**3**	**4**	**2**	**3**	**2**
Known fine	Mean	5.99	1.99	6.1	3.1	3.94	1.94	4.06	3.06
	Std. Dev.	2.02	2.02	2.06	2.06	1.42	1.42	2.36	2.36
	Mode	4.00	0.00	6.00	3.00	4.00	2.00	2.00	1.00
	Median	5.00	1.00	6.00	3.00	4.00	2.00	4.00	3.00
	# Obs.	160	160	176	176	152	152	112	112
Treatment 5		**Type 1 (s=4)**		**Type 2 (s=3)**		**Type 3 (s=2)**		**Type 4 (s=1)**	
		q	v	q	v	q	v	q	v
Theory		**7**	**3**	**6**	**3**	**4**	**2**	**3**	**2**
Fine in simple lottery form	Mean	6.53	2.53	5.46	2.46	4.24	2.24	3.16	2.16
	Std. Dev.	1.86	1.86	2	2	1.8	1.8	2.02	2.02
	Mode	6.00	2.00	5.00	2.00	4.00	2.00	3.00	2.00
	Median	6.00	2.00	5.00	2.00	4.00	2.00	3.00	2.00
	# Obs.	152	152	152	152	136	136	88	88
Treatment 6		**Type 1 (s=4)**		**Type 2 (s=3)**		**Type 3 (s=2)**		**Type 4 (s=1)**	
		q	v	q	v	q	v	q	v
Theory		**7**	**3**	**6**	**3**	**4**	**2**	**3**	**2**
Fine in compound lottery form	Mean	6.78	2.78	5.53	2.53	4.07	2.07	3.71	2.71
	Std. Dev.	1.82	1.82	1.83	1.83	1.73	1.73	2.41	2.41
	Mode	6.00	2.00	5.00	2.00	3.00	1.00	3.00	2.00
	Median	6.00	2.00	5.00	2.00	4.00	2.00	3.00	2.00
	# Obs.	152	152	152	152	144	144	128	128

Source: Authors.
The table shows the average, the standard deviation, the mean, the median, and the number of observations for (q) emission and (v) violation.

Table 5 shows the descriptive statistics, by type of firm, for the level of emissions and violations in the case of the treatments that induce violations. In this case, the results are different. The averages of violations take a lower value than the predicted expected profit maximizer model for the Type-1 firms, those with high marginal benefits and more lax emissions standards, in all treatments. On the contrary, violations are almost equal or are larger than those predicted by the model in the case of Type-3 and Type-4 firms, that is, those with lower marginal benefits but stricter standards. Meanwhile, Type-2 firms, those with high marginal benefits but stricter standards than Type-1 firms, behave as predicted, on average, in the case of known fines, but they show lower than predicted violations in the case of uncertain fines (treatments 5 and 6).

Similar to Caffera and Chávez (2013), we observe that in the case of uncertain fines, in general, the level of emissions achieved in the imperfect compliance treatments is lower than the level achieved in the case of perfect compliance treatments, although both were designed to induce the same levels of emissions in an expected profit maximizer subject.

4.2. Hypotheses tests

We are interested in comparing the frequency and the level of individual violations facing different levels of information regarding the amount of the fine. There are three types of fines: the certain fine, where the subjects know the amount of the fine corresponding to each level of violation, and two types of uncertain fines, one where the subject faces a simple lottery between two possible values for every possible level of violation and another where the subject faces a compound lottery. In both cases, the expected value of the lotteries is equal to the amount of the certain fine. Consequently, this leads to three comparisons. *Violations under a certain fine vs. violations under a simple lottery form of fine*: The null hypothesis here is that there are no differences between the individual average level of violation under a certain fine and the individual average level of violation under a simple lottery form of fine. The alternative hypothesis states that the level of violation differs between both types of fines. *Violations under a certain fine vs. violations under a compound lottery form of fine:* The null hypothesis is that there are no differences between the average individual level of violation under a certain fine and the individual average level of violation under a compound lottery form of fine. The alternative hypothesis states that the average level of violation differs between both forms of fines. *Violations under a simple lottery form of fine vs. violations under a compound lottery form of fine:* The null hypothesis is that there are no differences between the average individual violations across fines, while the alternative says that there are differences.

The results of the Mann-Whitney tests for each case are presented in Table 6. The overall result is fairly clear. In the cases where the treatments induce compliance and in the cases where the treatments induce violations, the difference in the information regarding the severity of the fine has no effect on the level of the individual average violation. The only exception arises in the comparison between the average level of individual violation with a certain fine and the average level of individual violation with a simple lottery form of fine in a perfect enforcement regime. In this case, the level of violation under a simple lottery form of fine (v_{sl})is higher than the level of violation under a certain fine(v_c). This is the only case where the additional risk introduced by the lottery form of fine causes a change in the violating behavior, increasing the level of non-compliance.

Table 6: Mann Whitney Test for all subjects per control type

Enforcement System		Known fine vs. Simple lottery fine			Known fine vs. Compound lottery fine			Simple lottery fine vs. Compound lottery fine		
		H_0: $v_c=v_{sl}$ H_1: $v_c \neq v_{sl}$			H_0: $v_c=v_{cl}$ H_1: $v_c \neq v_{cl}$			H_0: $v_{sl}=v_{cl}$ H_1: $v_{sl} \neq v_{cl}$		
		Rejected	Dif v_c-v_{sl}	Obs	Rejected	Dif v_c-v_{cl}	Obs	Rejected	Dif $v_{sl}-v_{cl}$	Obs
Induces perfect compliance	All firms	1%	-	1176	No		1176	No		1056
Induces violations		No		1128	No		1176	No		1104

Source: Authors. The observations consider the last 8 periods. v_c= violation with known fine; v_{ls}= violation in simple lottery form; v_{lc}= violation in compound lottery form.

Results do not change if we divide the subjects into two groups, high costs, subjects of Types 1 and 2, and low costs, subjects of Types 3 and 4, in the case of imperfect-enforcement regimes. For both types of firms, low cost and high cost, the level of certainty regarding the amount of the fines has no statistically significant effect on the level of violations (see Table 7). However, for the case of enforcement regimes that induce compliance, the results obtained in the previous tests, when we do not differentiate between high and low cost firms, are driven by high-cost firms (Types 1 and 2). Furthermore, for this type of firm, the effect of the information regarding the fine on the level of violation extends the comparison between a certain fine and a compound lottery form of fine. In this case, the violations of the high-cost firms are also higher in the event of an uncertain fine than they are in the case of a certain fine.

Table 7: Mann Whitney Test for all subjects per control type

Control System		Known fine vs. Simple lottery fine			Known fine vs. Compound lottery fine			Simple lottery fine vs. Compound lottery fine		
		H_0: $v_c=v_{ls}$ H_1: $v_c \neq v_{ls}$			H_0: $v_c=v_{lc}$ H_1: $v_c \neq v_{lc}$			H_0: $v_{ls}=v_{lc}$ H_1: $v_{ls} \neq v_{lc}$		
		Rejected	Dif v_c-v_{ls}	Obs	Rejected	Dif v_c-v_{rc}	Obs	Rejected	Dif v_r-v_{rc}	Obs
Complete	High (types 1y 2)	1%	-	600	1%	-	600	No		528
	Low (types 3 y 4)	No		576	No		576	No		528
Incomplete	High (types 1y 2)	No		640	No		640	No		608
	Low (types 3 y 4)	No		488	No		536	No		496

Source:Authors. The observations consider the last 8 periods. v_c= violation with known fine;v_{ls}= violation in simple lottery form;v_{lc}= violation in compound lottery form.

5. Conclusions

In this study, we used a laboratory economic experiment to analyze individual behavior compliance with an environmental policy based on emissions standards. The design considered exogenous variations in the stringency of enforcement to induce compliance under different degrees of information regarding the severity of the fine.

The results of the experiment indicate that when compliance is induced (complete enforcement) the subjects violate. Similarly, in the treatments where violations are allowed (incomplete enforcement), the levels of violations are lower than expected for the firms with higher costs and more lax similar standards and the levels of violations are greater for those with lower costs but more restrictive standards.

The first hypothesis we tested argues that in a system of emission standards under enforcement that induces compliance, the level of the violation of standards is independent from the level of information regarding the fine. The hypothesis is rejected when it is compared to a known fine versus a fine in simple lottery form as the level of infringement of the standard with a fine in simple lottery form is higher than the level of infringement under a known fine. However, the hypothesis is not rejected when contrasting the violations with a known fine versus infringements with fine in compound lottery form or when comparing infringement with a fine in simple lottery form versus compound lottery form. By separating the behavior of the firms with high costs from those with low costs, we observe that the difference mentioned herein is driven by the behavior of the firms with high costs, which infringe even more, on average, with a fine in compound lottery form versus a known fine.

Moreover, the information regarding the fine has an effect under enforcement designed to induce perfect compliance. When the individual levels of infringement are compared to known fines vs. uncertain fines in a system inducing infringement, it is not possible to reject the null hypothesis in all of these cases. Therefore, under incomplete enforcement, the degree of information associated with the fine seems irrelevant. Firms with high abatement marginal costs react to the information on the fine only in a control system that attempts to induce compliance. However, when the system is lax, the information on the fine is not relevant. A possible interpretation is that once the system is perceived as lax, the information regarding the fine neither adds nor detracts from the incentives affecting the decision to comply. It is only if the control system is not lax and the severity of the fine is known and certain that a difference in the level of infringement of companies is observed, especially in companies with high marginal costs.

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Annex 1: Additional Information

Table A.1. Behavior per period of subject who went bankrupt in each treatment

Treatment	Standard	q Theory	Period																			
			1		2		3		4		5		6		7		8		9		10	
			q	c	q	c	q	c	q	c	q	c	q	c	q	c	q	c	q	c	q	c
2	3	3	4	1	5	1	5	1	8	1												
3	3	3	5	1	3	0	5	1	5	1	6	1	6	1	7	1	8	1				
4	1	3	5	0	6	0	2	0	4	0	8	1	5	0	7	1	3	0	5	1		
4	1	3	9	0	8	1																
4	2	4	10	1																		
4	2	4	10	0	10	1																
4	1	3	10	1																		
4	1	3	10	0	2	0	2	0	1	0	10	1										
5	1	3	1	0	10	1																
5	2	4	5	0	6	1	8	0	6	1	8	1										
5	1	3	3	0	1	0	8	1														
5	1	3	2	0	3	1	4	0	4	0	6	1	5	0	10	1						
5	1	3	5	1	6	1																
5	1	3	5	0	6	0	6	1	5	0	6	1										
5	1	3	10	1																		
5	1	3	4	1	4	1	4	0	5	0	5	1	8	1								
5	2	4	5	0	6	0	7	0	7	1	10	0	10	1	10	0	10	1	10	0	10	1
5	1	3	10	0	10	1																
5	1	3	3	1	5	1	4	0	4	1	4	1										
6	1	3	3	1	10	1																
6	1	3	6	0	7	1																
6	1	3	4	0	8	0	10	0	5	0	10	0	10	0	10	1						
6	2	4	10	0	10	1																
6	1	3	10	1																		

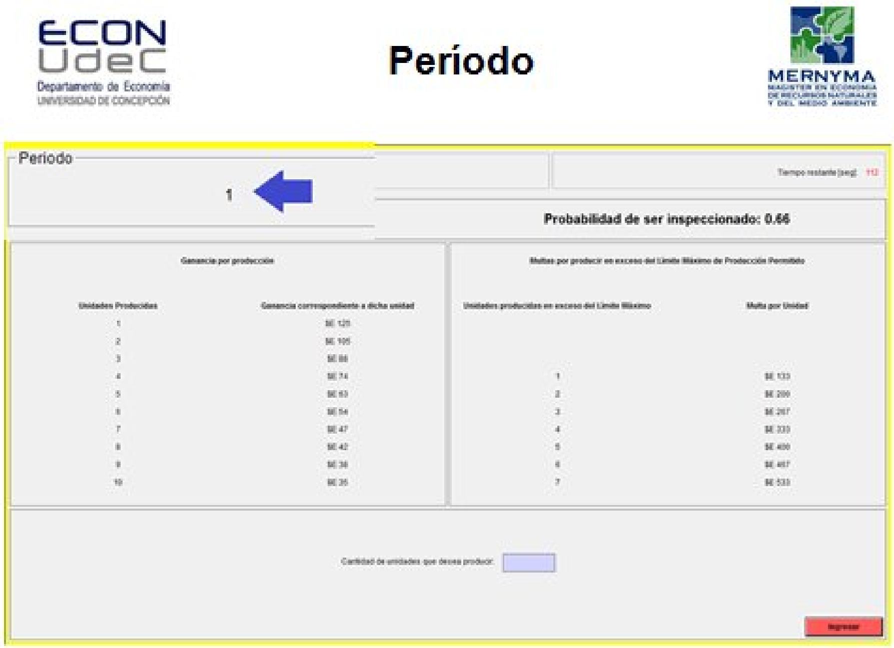
Source: Authors.
In the table, the behavior of the subjects per period that went bankrupt per treatment is presented in detail. Pointing general information as the treatment in which they participated, the standard imposed, and the level of emissions predicted by theory. Also, it is presented by period q: which represents the level of emissions c: which represents whether the subject was inspected/controlled during that period with value 1 in case of having being controlled, and 0 otherwise.

Table A.2. Detail of treatments conducted in each session

Session	Treatment	Compliance	Fine
1	2	Perfect	Risk
	3	Perfect	CompoundRisk
2	5	Violations	Risk
	6	Violations	CompoundRisk
3	3	Perfect	CompoundRisk
	2	Perfect	Risk
4	6	Violations	CompoundRisk
	5	Violations	Risk
5	1	Perfect	Known
	4	Violations	Known
6	4	Violations	Known
	1	Perfect	Known
7	1	Perfect	Known
	4	Violations	Known
8	5	Violations	Risk
	6	Violations	CompoundRisk
9	2	Perfect	Risk
	3	Perfect	CompoundRisk

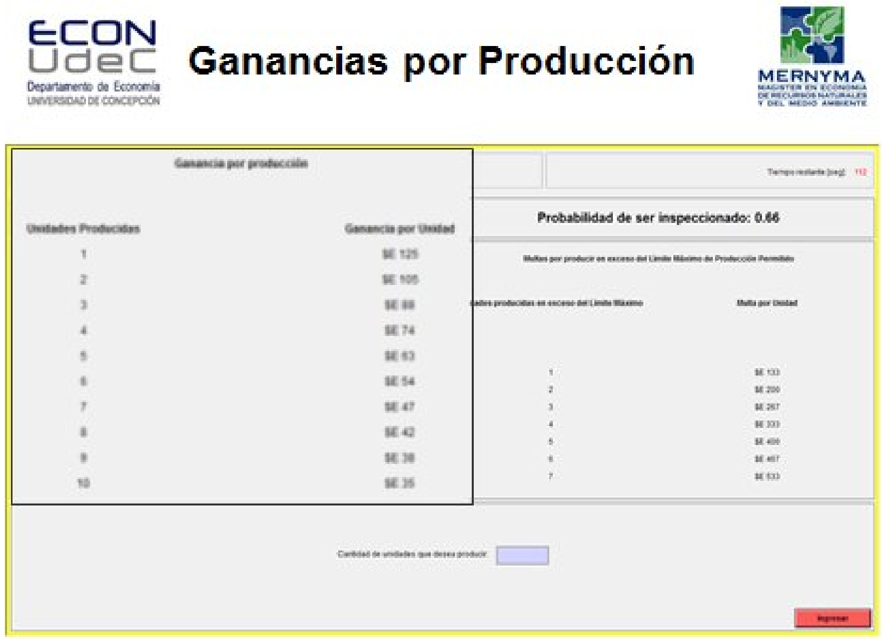
Source: Authors.
In this table the treatments conducted in each experimental session are presented in detail.

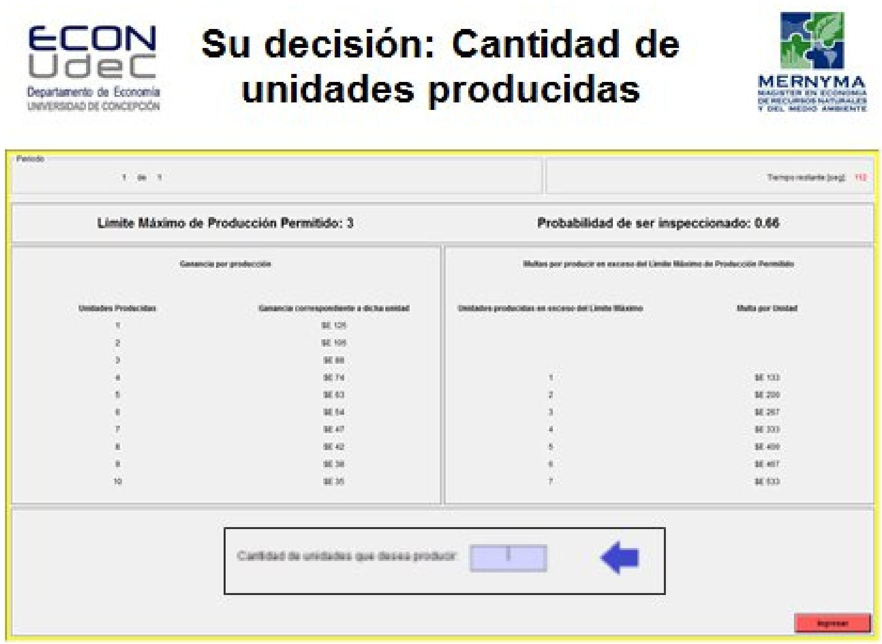
Annex 2: Slideshow with instructions



ECON
UdeC
Departamento de Economía
UNIVERSIDAD DE CONCEPCIÓN
Período
MERNYMA
Periodo
1
Probabilidad de ser inspeccionado: 0.66

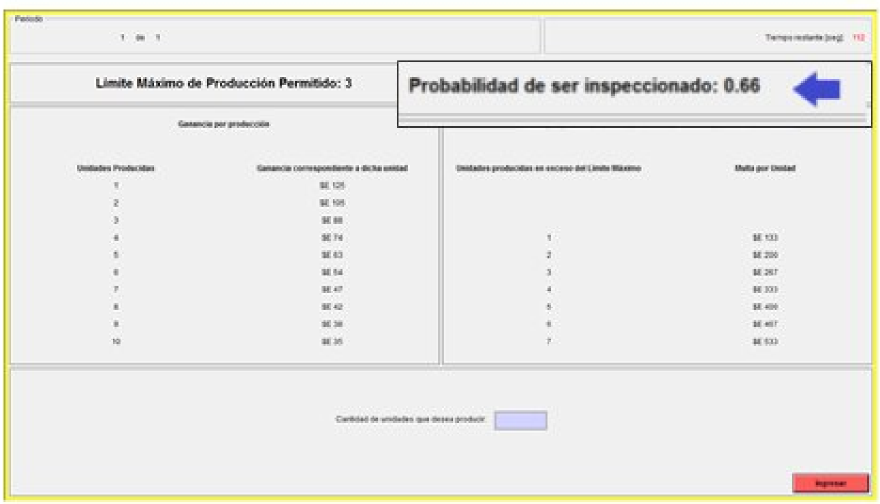
ECON
UdeC
Departamento de Economía
UNIVERSIDAD DE CONCEPCIÓN
Límite Máximo de Producción Permitido
MERNYMA
Límite Máximo de Producción Permitido: 3


ECON UdeC
Departamento de Economía
UNIVERSIDAD DE CONCEPCIÓN
Ganancias por Producción
MERNYMA
Ganancia por producción
Unidades Producidas
Ganancia por Unidad
1 $E 125
2 $E 105
3 $E 88
4 $E 74
5 $E 63
6 $E 54
7 $E 47
8 $E 42
9 $E 38
10 $E 35
Probabilidad de ser inspeccionado: 0.66


ECON UdeC
Departamento de Economía
UNIVERSIDAD DE CONCEPCIÓN
Su decisión: Cantidad de unidades producidas
MERNYMA
Límite Máximo de Producción Permitido: 3
Probabilidad de ser inspeccionado: 0.66
Cantidad de unidades que desea producir:

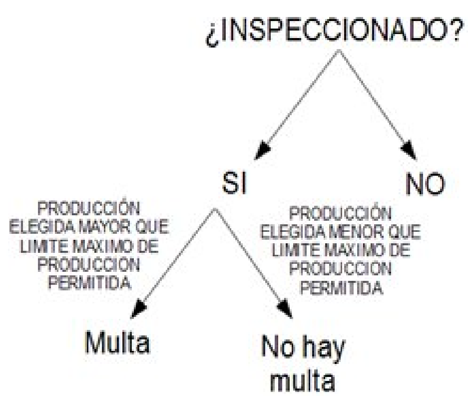
Tiempo restante

La Probabilidad de ser Inspeccionado

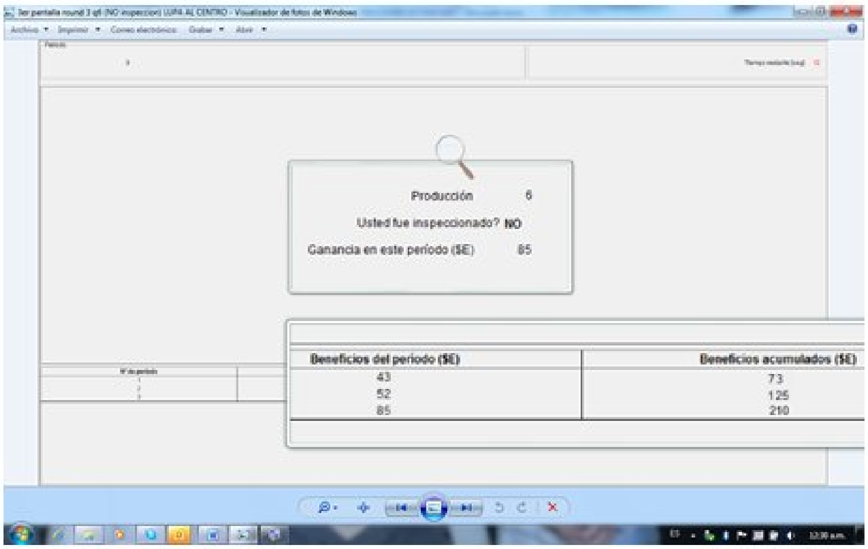


Multa por producir en exceso del límite máximo permitido

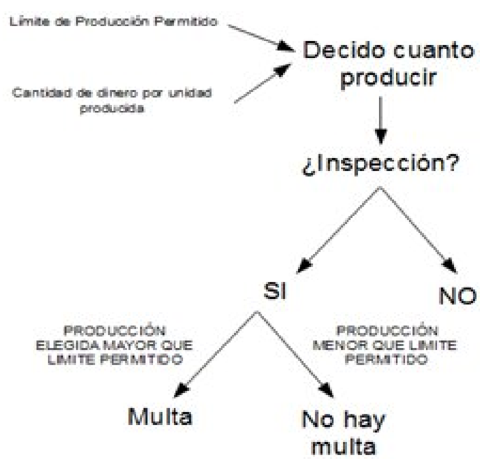
Inspección



Ingresos del período



Resumen: Procedimiento



Resumen:Ganancias