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by

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Why Do Environmental Taxes Work Better in Developed Countries?

Jessica Coria[(a)], Clara Villegas-Palacio[(b)], and Juan Camilo Cárdenas[(c)]

Abstract

We compare of the performance of emission taxes between Colombia and Sweden in an experimental setting where subjects are regulated through environmental taxes and had to decide on emission levels, compliance behavior, and adoption of an environmentally friendly technology. Our design allows us to analyze the role of variations in the stringency of the policy enforcement by regulatory agencies in two different cultural contexts. In line with previous literature that emphasizes the role of social norms and intrinsic motivations explaining compliance behavior, we find that actual emissions and tax underreporting are lower than predicted by traditional models that are solely based on self-interested preferences. However, we find that for an equivalent monitoring stringency, there are no statistically significant differences in emission levels and compliance behavior between Colombian and Swedish subjects. This is to say that despite the positive effect of social norms enhancing compliance, a more stringent enforcement remains as an important mechanism to induce firms to comply with the regulation.

***JEL classification*:** C91; L51; Q58

***Key words*:** laboratory experiments, emission taxes, imperfect monitoring, technology adoption, developing countries, cross-country comparison, Colombia, Sweden.

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I. Introduction

Over the last decades, the role that environmentally related taxes have had in environmental policies has grown in developed countries. They have shown to be efficient instruments that lead to “cost-effective” allocations of the burden of achieving given levels of environmental protection among firms; they also provide continuous incentives for adoption of environmentally superior technologies, as it is always in the interest of firms to clean up more, rather than pay emission taxes, if sufficiently inexpensive abatement technologies are available (OECD 2010).

The positive outcomes from environmental taxation have led many donors and advisors to promote the use of environmental taxes as the key to more effective environmental protection in the developing world (Coria and Sterner 2010). However, to ensure compliance with emission taxes, the regulator must enforce the regulation by monitoring compliance and punishing transgressors. Since in developing countries there are often institutional and economic constraints that limit the regulator’s ability to frequently monitor a large proportion of all regulated firms and/or to impose relatively high fines to deter firms from violating regulations, some economists have argued that they do not perform as well in developing countries as they do in developed countries (see Blackman and Harrington 2001 and Bell and Rusell 2002).

However, several papers have shown that tax compliance cannot be explained entirely by the stringency of monitoring and enforcement (see for instance Alm, Sanchez, and De Juan 1995; Frey and Feld 2002; Torgler 2002; and Cummings et al. 2009). Indeed, even though most countries set the levels of monitoring probability and penalty relatively low, which should tempt most “rational” individuals to evade taxes, a high degree of compliance is observed (Torgler 2002). This paradox can be explained by very high levels of risk aversion, and it is also plausible that tax compliance is affected by other factors such as government services, trust in institutions and perception of others’ tax compliance (Frey and Feld 2002). Cross-cultural differences in tax compliance behavior are also very common (see for instance Torgler 2004; Hyun 2005; Cummings et al. 2009) and seem to have a foundation in socially transmitted rules about how to behave in certain circumstances. Internal social norms – defined as the perceptions of other taxpayers’ law obedience and information about other taxpayers’ behavior regarding tax compliance – have a positive effect on tax morale. The same holds for external social norms, measured as trust in the government and the legal system and citizen’s assessment of the quality of governance.

Unfortunately, empirical evidence that can be used to compare the performance of environmental taxes in developed and developing countries is not easily available due to the paucity of environmental taxes in developing countries. Furthermore, the rather scarce empirical evidence available does not allow disentangling the role of the national social norms and culture from the lack of institutional capacity and resources among regulatory agencies in developing countries. In this paper, we tackle the relative importance of these issues using data obtained via laboratory experiments. Unlike previous studies comparing tax compliance across countries, we focus on the effect of monitoring probability in different cultural settings by performing a between-country comparison of the effects of different monitoring probabilities on compliance with environmental taxes and on adoption of an environmentally-friendly technology. Our choice is based on empirical evidence that indicates that monitoring probability is the best predictor of good environmental performance in developing countries (Dasgupta et al. 2001). This might be explained by the fact that regulators interact with firms in more than one context and over many periods. Hence, a higher monitoring probability augments the incentives for compliance beyond the avoidance of immediate fines since non-compliance implies a threat of more extensive scrutiny in the future.[1]

For our cross-country comparison, we chose Colombia and Sweden. According to the 2010 Environmental Performance Index (EPI), which ranked 163 countries on 25 performance indicators covering both environmental public health and ecosystem vitality, both countries are ranked among the three most environmentally friendly countries in their respective geographic regions (with Sweden ranked fourth and Colombia ranked tenth in the overall ranking). Furthermore, even though they both have environmental taxes in place, they differ markedly in terms of enforcement stringency and compliance levels. We can in this context compare for example Colombia's water discharge fee program and the NOx charge in Sweden, two primary examples of the use of environmental taxes to reduce pollution (Sterner and Coria 2011). Though Colombia's discharge fee system for water effluents is often mentioned as a model of well-functioning economic policy in a developing country, the most important implementation problem experienced in practice is the broad non-compliance by the main dischargers (Caffera 2010). The lack of compliance by this group has undermined the "culture of compliance," since smaller polluters in industry and agriculture complain loudly about being made to pay the fees when many of the largest polluters fail to do so. Furthermore, evidence suggests that the good performance of the scheme is limited to the few

[1]Slemrod et al. (2001) analyze the taxpayers' response to a random increased probability of audit in Minnesota. They find that such increased probability has a higher effect on taxpayers with a history of non-compliance.

regions where the local regulatory authority is better equipped to enforce the regulation (Sterner and Coria 2011). In contrast, the NOx charge in Sweden is rather successful and stringent: continuous monitoring is used to measure emissions for most plants, and the policy has brought considerable technological progress in lowering emission intensities (Blackman and Harrington 2001, Höglund 2005 and Sterner and Turnheim 2009).

Why do environmental taxes work better in Sweden? Our results support the role of weak regulatory enforcement as an important driver of the poor performance of environmental taxes in developing countries. In line with previous literature that emphasizes the role of social norms and intrinsic motivations (see Bowles and Polania 2011), we find that actual emissions and tax underreporting are lower than predicted by a traditional model that excludes such motivation. However, we find no statistically significant differences in emission levels and compliance behavior between Colombian and Swedish subjects for the same monitoring probability. This is to say that despite their cultural differences and histories of compliance, a more stringent enforcement remains as an important mechanism to induce firms to comply with the regulation and, in this setting, to invest in environmentally friendly technologies.

The paper is organized as follows. In Section 2 we set up the model used to compare the incentives provided by emissions taxes and introduce the hypotheses to be tested through the experiments. In Section 3 we describe the experimental setting. In Section 4 we present some descriptive statistics of our samples. We compare emissions, non-compliance and the rate of technology adoption between the Colombian and Swedish subjects, and then analyze the influence of some behavioral characteristics of our participants on our results. Finally, Section 5 concludes the paper.

2. Theoretical framework

We follow Villegas-Palacio and Coria's (2010) theoretical setting to develop hypotheses related to adoption of new technologies and compliance behavior under emission taxes. In the following paragraphs we briefly synthesize the model. However, we recommend the reader to review their paper for further details.

Villegas-Palacio and Coria (2010) consider a competitive industry consisting of a continuum of firms of mass 1 that are risk neutral. The firms are initially homogeneous in the abatement cost $c(e)$, which is strictly convex and decreasing in emissions. In the absence of environmental regulation, each firm emits a quantity e_0 of a homogeneous pollutant. They assume that the environmental authority sets a maximum level of emissions and then chooses an emission tax t to reach this target. Firms are required to self-report their emissions. The reported emissions level is denoted as r.

Since the regulator cannot observe firms' emissions, costly monitoring is undertaken. The probability of being monitored is known by firms and equal to π. Once the regulator monitors a firm, it is able to perfectly determine the firm's compliance status. If the monitoring reveals that the firm is non-compliant, it faces the penalty $\phi(v)$, which is s a strictly convex function of the extent of violation $v = e - r$. For zero violation, the penalty is zero $\phi(0) = 0$, but the marginal penalty is greater than zero, i.e., $\phi(0) > 0$.

A new and more efficient technology arrives and firms must decide whether or not to invest in it. The new technology allows firms to abate emissions at a lower cost, given by $\theta c(e)$ where $\theta \in (0,1)$ is a parameter that represents the drop in abatement cost due to adoption of the new technology. They assume that buying and installing the new technology implies a fixed cost that differs among firms. Let k_i denote the fixed cost of adoption for firm i, where k_i is uniformly distributed on the interval $(\underline{k}, \overline{k})$ with density function $f(k_i)$ and cumulative distribution function $F(k_i)$. Let μ_{NAi} and μ_{Ai} be firm i's total expected costs of abatement and compliance when using the current abatement technology (non-adoption) and new technology (adoption), respectively, such that the expected cost savings from adopting are $\mu_{NAi} - \mu_{Ai}$. Any firm whose expected cost saving offsets its adoption cost will adopt the new technology. Therefore, the adoption rate – denoted λ – depends on the total expected savings in the costs of abatement and compliance, which are endogenous to the stringency of the environmental and enforcement policy in place.

Regarding the interaction between regulator and firms, it is as follows:

1. Before the arrival of the new technology, the regulator determines and announces a uniform unitary tax level t, a monitoring probability π, and a monetary sanction scheme $\phi(v)$,
2. The firms make adoption decisions as well as decide their actual and reported emissions levels e and r, respectively, which defines the violation level v
3. The regulator monitors the firms according to the announced monitoring probability and sanctions those found in non-compliance according to the sanctioning scheme.

In this setting, the problem of an adopter is the following:[2]

$$(1) \quad Min_{e,r}\mu_A = \theta c(e) + tr + \pi\phi(e - r),\ s.t. \quad e - r \geq 0.$$

Solving this minimization problem, if the solution is interior, each firm chooses its emission levels such that the marginal abatement cost equals the tax rate. Since there is a uniform tax rate, in equilibrium firms' marginal abatement costs are equal irrespective of their adoption status, i.e., $c'(e_{NA}) = \theta c'(e_A)$. Therefore, adopters' actual levels of emissions are reduced due to the availability of the new technology and are lower than those of non-adopters. In addition, since the tax is exogenous and not influenced by the enforcement strategy, firms' actual emissions do not depend on the parameters of the enforcement problem.

On the other hand, firms choose to report a level of emissions such that the marginal benefit of non-compliance (given by the tax) equals the marginal expected fine, i.e., $t = \pi\phi(e - r)$. Since both the tax rate and the enforcement policy are the same for adopters and non-adopters, it follows that the extent of violation is the same for both types of firms, i.e., $e_A - r_A = e_{NA} - r_{NA}$. Given that adopters' emissions are lower than non-adopters' emissions, it follows that the emissions reported by adopters are lower than those reported by non-adopters. Moreover, the reported levels of both adopters and non-adopters are decreasing in the tax rate and increasing in the monitoring probability. This implies that the extent of violation increases in the tax rate and decreases in the monitoring probability. (see Villegas and Coria 2010, page 280).

Finally, the difference between the expected costs of abatement and compliance under the current and the new technology can be expressed as:

$$(2) \quad \mu_{NA} - \mu_A = [c(e_{NA}(t)) - \theta c(e_A(t))] + t[e_{NA}(t) - e_A(t)].$$

Hence, given the definition of the uniform cumulative distribution of k_i, the adoption rate can be characterized as the fraction of the adoption cost savings $\mu_{NA} - \mu_A$, as follows:

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[2] The problem of the firms that do not adopt the new abatement technology is analogous to problem (2); the main difference is that the abatement costs for these kinds of firms are given by $c(e)$ instead of $\theta c(e)$.

(3) $\lambda^{Tax} = \psi\{c(e_{NA}(t)) - \theta c(e_A(t)) + t[e_{NA}(t) - e_A(t)]\} - \xi,$

where $\psi = \frac{1}{\bar{k}-\underline{k}}$ and $\xi = \frac{\underline{k}}{\bar{k}-\underline{k}}$.

Note that since neither the emissions level nor the tax rate is a function of monitoring probability or of the sanction structure, the enforcement strategy does not affect the rate of adoption.

In sum, the hypotheses to be tested are:

Hypothesis 1: With emission taxes, the emission level is independent of the monitoring probability. Moreover, adopters of the new technology have lower emissions than non-adopters.

Hypothesis 2: With emission taxes, the extent of violation of firms is independent of the adoption status, but it decreases in the monitoring probability.

Hypothesis 3: With emission taxes, the adoption rate does not depend on the monitoring probability.

3. Experimental design and procedures

3.1 Experimental design

Our experiments were framed in the context of a firm that is regulated by emission taxes.[3] As a result of its production, it has an initial level of emissions e_0 of 10 units before any abatement process. The firm has a current abatement technology represented by the marginal abatement cost function $c_0'(e_0\text{-}e) = 400[e_0\text{-}e]$. A new and more efficient abatement

[3]Some experimentalists suggest that experiments should not be framed in any particular context to avoid that this influences the results (see for instance Murphy and Cárdenas 2004), but there is no consensus on this. We frame our experiment in the context of environmental compliance since we want to capture the effect of intrinsic motivations to comply with regulations and to adopt new technologies, which could potentially be affected by attitudes with respect to the environment. However, we do not think of this as a problem given our between-subjects design and that the participants were randomly assigned to each treatment.

technology is available; it is represented by the abatement cost function $c_1^{'}(e_0\text{-}e) = 160[e_0\text{-}e]$. The unitary tax is 500 tokens.

Subjects were randomly assigned a fixed cost of adoption in the range [10, 2500] and were then asked to decide: (1) whether or not to buy and install a new and more efficient abatement technology, (2) how many units (of the initial emissions level) to abate, which determines the actual emissions level e, and (3) how many units of the actual emissions level to self-report to the authority, which determines the reported level $r \in [0, e]$.[4] Finally, (2) and (3) determine the extent of the violation $v = e - r$.

At the end of the round the authority monitored some firms to verify that the reported emission level coincided with the actual emission level. Each firm faced the same monitoring probability, which was publicly announced before firms had to make decisions. Since the monitoring probability is one of our treatment variables, it varies across treatments, as described in Table 1. In the first treatment, only 7 out of 18 participants are monitored (that is 40% of the subjects). In the second treatment, 90% of the participants were monitored. The difference between the two monitoring probabilities intends to reflect the stringency of the enforcement schemes observed in developing and developed countries. As mentioned previously, while direct and continuous monitoring of emissions has been an important factor in the success of environmental programs in developed countries (Stranlund et al. 2002), the enforcement design used in less developed countries has not induced a high level of compliance (Wang and Wheeler 2005, Coria and Sterner 2010).

When caught in violation, the firm was sanctioned according to a penalty schedule given by $\phi = 100v^2 + 250v,$ where the convexity of the schedule, together with the convexity of the abatement cost function, guarantees that the second order conditions of the minimization problems in equations (1) and (2) are satisfied.

Table 1: Experimental design

Monitoring probability	Colombia	Sweden
Low (π = 40%)	Treatment 1	Treatment 3
High (π = 90%)	Treatment 2	Treatment 4

[4]Note that there are no benefits of reporting more emissions than the actual level, since in such case the firm has to pay the tax per unit of excess emissions. Instead, the firm might want to underreport in order to reduce the tax payment.

3.2 Experimental procedure

Participants were recruited from the business management and administration engineering undergraduate programs at the National University of Colombia (in Medellin) and the University of Gothenburg in Gothenburg, Sweden. Subjects were randomly selected from a list of people who registered in response to an e-mail invitation to participate in the experiment. We ran two treatments (with three sessions per treatment) in each country. Students in Colombia were paid COP 5,000 for participating in the experiment and showing up on time and earned an average of COP 23,800. Students in Sweden were paid SEK 60 for participating and showing up, and earned an average of SEK 153.[5]

In each country, the experiment was run in a computer lab with a specially designed Excel worksheet that calculated additional earnings for all possible combinations of adoption decisions, actual emissions level, and/or reported emissions. Each session lasted around 90 minutes. Each participant was randomly assigned an identification number at the beginning of the session that determined the fixed adoption cost. They were also handed the instructions, which were read aloud by the experimenter in Spanish and Swedish, respectively.[6] To make the participants familiar with the experiment, a set of control questions was included in the instructions. In order to answer the control questions, the participants needed to operate the same Excel worksheet that was used in the experiment but with a different set of parameters. Appendix A (available on request) shows the instructions and what the Excel worksheet looked like. Answers to the control questions were not considered in the analysis. After all participants had completed the training and all questions had been answered, the experiment began.

All participants had 20 minutes to make their decisions. Once all participants had made their decisions, the cards where they had reported their decisions, called the experimental cards, were collected by the experimenter and the monitoring stage started. To select the firms that were going to be monitored, the experimenter had cards with all the participants' numbers in a bag. In front of the participants, the experimenter randomly selected and read aloud the numbers of the cards that corresponded to the participants that were going to be monitored.

[5] In cases with samples with different opportunity costs, either the absolute amount in the experiment or the opportunity cost can be kept constant. We decided to keep the opportunity cost constant; it should be noted that Kocher et al. (2008) did not find a significant stake effect in a one-shot public goods game. The exchange rate at the time of the experiment was US$ 1 = approximately COP 1,800 and US$1 = approximately SEK 7. For the sake of illustrating opportunity costs, in both countries the average earning would cover a ticket to a movie and a snack.

[6] The instructions were written in Spanish, translated to Swedish and then back to Spanish to check for accuracy of the translations.

The result of the monitoring procedure, i.e., the compliance status, was kept secret to the participants. The participants knew about the anonymous character of their decisions.

After the monitoring stage had been completed, the final questionnaire was handed out to the participants. Given that our experimental design included a stochastic regulatory process, the first part of the questionnaire aimed at measuring risk preferences. To this end we had an incentivized risk experiment adapted from the risk experiment by Holt and Laury (2002). The subjects were faced with a menu of 10 paired lottery choices; in each case they had to choose between two lotteries, A and B. The payment for lottery A was constant, riskless and equal to USD 2.77; lottery B was risky, but offered twice as much as lottery A. In the first paired lottery, the probability of the high payoff under lottery B was 9/10. In the second, it was 8/10, and it decreased systematically through the sequence of paired lotteries. When the probability of the high payoff outcome decreases to a certain point, a person should cross over to lottery A. Hence, the crossover point from the risky to the riskless lottery can be used to infer the degree of risk aversion. Clearly, the lower the probability of the high payoff at which subjects switch to lottery A, the lower the risk aversion since subjects then demand a lower expected compensation in order to turn down the risky alternative.

Subjects were told from the beginning that at the moment of payment one of the choice sets was going to be randomly selected for the payment. For that purpose, two 10-sided dice were used. One of the dice was used to randomly choose one of the 10 lottery pairs. If the participant had chosen alternative B in that set, the other one was used to actually play the lottery. Finally, once all participants had handed in the final questionnaire, they were privately paid in cash, receiving the show-up fee, the earnings from the experiment, and the earnings from the risk experiment.

4. Results

In this section we analyze the results of our experiment. First, we present some descriptive statistics of the socio-economic and self-reported attitudinal characteristics of our participants, as well as non-parametric tests of the null hypothesis that our samples do not differ. Second, we compare the actual emission levels, non-compliance behavior (i.e., underreporting), and rate of technology adoption. Finally, we analyze the influence of some behavioral characteristics of our participants on the results.

4.1 Comparing attitudes toward environmental protection, compliance, and technological change

Non-parametric Wilcoxon-Mann-Whitney tests indicate that our samples do not differ in gender composition or risk attitudes (based on the answers to the incentivized risk experiment described in the previous section). However, the subjects sampled in Sweden were significantly older and richer (in nominal terms)[7] than the subjects in Colombia (see Table 2).

Table 2: Non-parametric tests of socio-demographic characteristics.

Characteristic	Colombia	Sweden	p-value
Male (%)	58.490	67.742	0.179
Age (years)	21.490	23.462	0.000***
Risk attitudes	55.283	57.634	0.461
Monthly expenses (USD)	207.143	761.905	0.000***

(***) statistically significant at 1%, (**) statistically significant at 5%, (*) statistically significant at 10%.

Non-parametric tests of the self-reported attitudes toward environmental protection and the environment also indicate that the Swedish participants are more positive toward technology than are Colombian participants. On the other hand, there are no statistical differences in the importance assigned to environmental protection. Indeed, we asked them to choose which of the following statements was closest to their opinion: (a) “Protecting the environment should be given priority, even if it causes slower economic growth and some loss of jobs,” (b) “Economic growth and generation of jobs should be a priority even if the environment suffers a bit,” and (c) other answer. We find that the fraction of participants who chose option (a) does not differ significantly in size between Sweden and Colombia. This and the answers to the question about how well represented they were by the statement “For this person, it is very important to look after the environment” indicate that our samples do not differ with respect to the importance assigned to protection of the environment.

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Table 3: Non-parametric tests of attitudes toward technology and the environment.

Attitudes toward technology (1: completely disagree, 10: completely agree)	Colombia	Sweden	p-value
Science and technology are making our lives healthier, easier, and more comfortable.	6.528	7.322	0.011**
Because of science and technology, there will be more opportunities for the next generation.	6.547	7.677	0.000***

[7] The income difference in real terms is much smaller, though it is still statistically significant. For instance, US $207 would allow a Colombian student to go watch a movie 37 times in a month, whereas US $761 would allow a Swedish student to do the same thing 41 times in a month.

Science and technology make our way of life change too fast.	8.702	8.489	0.032**
Importance of environmental protection			
For this person it is important to look after the environment (1: Very much like me, 6: Not at all like me)	2.152	2.452	0.178
Fraction of subjects for whom the following statement comes closest to their own opinion: "Protecting the environment should be given priority, even if it causes slower economic growth and some loss of jobs."	49.051%	59.142%	0.161

(***) statistically significant at 1%, (**) statistically significant at 5%, (*) statistically significant at 10%.

We also asked the participants to state how strongly they agree with some statements regarding the distribution of the costs of environmental protection. We did not find any statistically significant difference in the mean of the answers between our sample pools. On average, the subjects want the government to reduce environmental pollution without cost to them. However, we did find some differences in the direction of the responses as presented in Table 4. For instance, Colombian subjects seem slightly more reluctant to give up part of their income for environmental protection. Furthermore, increased taxes are quite unpopular among our subjects even when the revenues are used are used to prevent environmental pollution. However, the fraction of Colombian subjects who disagree or strongly disagree with an increased tax burden is larger than for the Swedish subjects. This can be clearly related to the fact that Swedish citizens are accustomed to high rates of taxation as Sweden has one of the highest overall tax-to-GDP ratios in Europe and in the whole world (46.9% in 2009; see Eurostat 2011). Furthermore, since the early 1990s, Sweden has introduced several environmental taxes as part of a comprehensive green tax reform (Sterner and Coria 2011).

Table 4: Non-parametric tests of attitudes toward the cost of environmental protection.

Distribution of the cost of environment protection (1: Strongly agree, 4: Strongly disagree)	**Colombia**	**Sweden**	**p-value**
I would give up part of my income for the environment	2.933	2.924	0.927
(%) of subjects who strongly agree or agree (1,2)	21.905	27.957	0.563
(%) of subjects who disagree or strongly disagree (3,4)	78.095	72.043	0.091*
I agree with tax increases if the extra revenues are used to prevent environmental pollution	2.953	3.000	0.348
(%) of subjects who strongly agree or agree (1,2)	20.755	23.656	0.064*
(%) of subjects who disagree or strongly disagree (3,4)	79.245	76.344	0.015**
The Government should reduce environmental pollution, but it should not cost me any money	2.324	2.206	0.180
(%) of subjects who strongly agree or agree (1,2)	65.714	70.652	0.027**
(%) of subjects who disagree or strongly disagree (3,4)	34.286	29.348	0.059*

(***) statistically significant at 1%, (**) statistically significant at 5%, (*) statistically significant at 10%.

Surprisingly, mean self-reported attitudes toward compliance with regulations are not statistically different between the Swedish and Colombian subjects (see Table 5).[8] In each country, most subjects agree or strongly agree with the statement "Environmental regulations should not be violated in any situation"[9], and disagree or strongly disagree with the statement "Environmental regulations should not be violated only because it is illegal"[10]. They also state that they would feel guilty and ashamed if violating regulations; in both countries, guilt and shame increase statistically when the authority gets to know about non-compliance.

Table 5: Non-parametric tests of attitudes toward compliance with environmental regulations

Compliance with regulations	Colombia	Sweden	p-value
Suppose you are not complying with a regulation, but neither the authority nor society finds out about it. You would feel: (1: Not guilty at all, 5: Extremely guilty)	3.415	3.226	0.429
Suppose you are not complying with a regulation, but neither the authority nor society finds out about it. You would feel: (1: Not ashamed at all, 5: Extremely ashamed)	3.179	3.118	0.681
Suppose you are not complying with a regulation and the authority finds out about it. You would feel (1: Not guilty at all, 5: Extremely guilty)	4.245	4.376	0.122
Suppose you are not complying with a regulation and the authority finds out about it. You would feel (1: Not ashamed at all, 5: Extremely ashamed)	4.339	4.172	0.282
Environmental regulations should not be violated in any situation (1: Absolutely disagree, 5: Absolutely agree)	4.286	4.129	0.377
Environmental regulations should not be violated only because it is illegal (1: Absolutely disagree, 5: Absolutely agree)	2.113	2.043	0.546
Suppose a person is violating a regulation. You think of this (1: As absolutely unacceptable, 5: As absolutely acceptable)	2.552	2.548	0.937
Knowledge of environmental regulations			
Do you know if there are emission taxes in place in your country?(1 if the subject knows, and 0 otherwise)	0.349	0.581	0.001***

$^{(***)}$ statistically significant at 1%, $^{(**)}$ statistically significant at 5%, $^{(*)}$ statistically significant at 10%.

Finally, regarding people's knowledge of environmental regulations in place in their countries, more than half of the Swedish subjects are aware of the existence of environmental

[8] This evidence is in line with Torgler (2004), who compares tax morale in Costa Rica and Switzerland. He finds a slightly higher tax morale in Costa Rica. Furthermore, his results indicate that internal and external social norms have a significant effect on tax morale and tax compliance.

[9] The total fraction of subjects that agree or strongly agree with this sentence is equal to 87.73% in Colombia and 86.02% in Sweden.

[10] The total fraction of subjects that disagree or strongly disagree with this sentence is equal to 70.75% in Colombia and 74.19% in Sweden.

taxes in the country, while only 35% of the Colombian subjects state to know about the existence of environmental taxes in Colombia. This is consistent with the high prevalence of environmental taxes in Sweden compared to in Colombia.

4.2 Comparing actual emission levels and extent of violation

From the theoretical model described in previous sections we derive the hypothesis that adopters of the new technology have a lower average emission level than non-adopters. The experimental results support the hypothesis in both Colombia and Sweden as shown in Table 6, which presents the expected and average actual emission levels for both groups in each country. In line with the theoretical model, the results show that adopters' emissions are lower than those of non-adopters irrespective of monitoring probability. Note, also from Table 6, that actual emission levels are lower than predicted by the model by Villegas-Palacio and Coria (2010) for the given sets of parameters. This is an indication of the role that behavioral variables such as intrinsic motivations and social norms have on compliance behavior. When comparing between countries we observe that when the monitoring probability is low there are no statistical differences in the actual emission levels, neither for adopters nor for non-adopters. This picture slightly changes when the monitoring probability is high since Swedish non-adopters have an actual emission level that is statistically higher than that of Colombian non-adopters.

Table 6: Non-parametric test of emission levels in Colombia and Sweden

Group	Expected emissions	Low monitoring probability			High monitoring probability		
		Colombia	Sweden	p-value	Colombia	Sweden	p-value
Adopters	6.90	6.257	5.750	0.537	6.307	5.824	0.580
Non-adopters	8.50	8.210	8.393	0.568	8.346	9.107	0.015**
p-value	-----------	0.000***	0.000***	---------	0.000***	0.000***	---------

(***) statistically significant at 1%, (**) statistically significant at 5%, (*) statistically significant at 10%.

When it comes to under-reported emissions, the theoretical model predicts that both adopters and non-adopters have the same extent of violation for a given monitoring probability. From our experimental results we do not find evidence to reject this hypothesis when the monitoring probability is high. However, we do find evidence to do so when the monitoring probability is low as non-adopters´ extent of violation is higher than that of adopters.

The theoretical model also predicts that the extent of violation of both adopters and non-adopters goes down when the monitoring probability increases. According to the experimental results, we cannot reject this hypothesis. Additionally, as shown in Table 7, the average extent of violation for adopters and non-adopters is generally lower than predicted by the theoretical model in both countries. As mentioned before, this indicates that the monitoring probability and the sanction scheme are not the only determinants of compliance with regulations as predicted by traditional models of economics of crime. Moreover, for a given probability of being audited, we observe no statistical difference in the extent of violation between Colombian and Swedish subjects. If we argue that the self-reported attitudes toward compliance described in Table 5 are a good proxy for intrinsic motivations and social norms concerning compliance with environmental regulations, the fact that there is no statistical difference in compliance behavior between Swedish and Colombian subjects is consistent with our empirical finding that there are no significant differences in self-reported attitudes toward compliance between the two subjects pools.

Table 7: Non-parametric test of violation level for adopters and non-adopters of the new technology in Colombia and Sweden

Group	Low monitoring probability				High monitoring probability			
	Expected	**Colombia**	**Sweden**	**p-value**	**Expected**	**Colombia**	**Sweden**	**p-value**
Adopters	5.0	2.429	2.10	0.278	1.6	1.231	1.294	0.814
Non-adopters	5.0	3.737	3.464	0.878	1.6	2.038	1.893	0.845
p-value	-----------	0,014**	0.036**	---------	-----------	0.225	0.340	---------

(***) statistically significant at 1%, (**) statistically significant at 5%, (*) statistically significant at 10%.

Table 8 displays the deviation from the expected violation for each country and monitoring probability (i.e., the difference between the expected violation and the actual level). Interestingly the extent of this deviation is statistically higher when the monitoring probability is low in both Colombia and Sweden. This is to say that subjects violate to a much lower extent that predicted by a model solely based on self-interested preferences when the “threat” of inspection is lower. Moreover, adopters’ deviation from the expected violation is also statistically higher when the monitoring probability is low. This observation is consistent with reciprocity; a lower monitoring probability signals that the regulator trusts the firms, which triggers a less self-interested response and reduces the extent of violation.

Table 8: Deviation from the expected violation for adopters and non-adopters of the new technology in Colombia and Sweden

Group	Colombia			Sweden		
	Low Probability	High Probability	p-value	Low Probability	High Probability	p-value
Adopters	2.571	0.369	0.000***	2.900	0.306	0.001***
Non-adopters	1.263	-0.438	0.002***	1.536	-0.293	0.007***
p-value	0.014**	0.225	---------	0.036**	0.340	---------

(***) statistically significant at 1%, (**) statistically significant at 5%, (*) statistically significant at 10%.

Given the set of parameters, the theoretical model predicts that all subjects in the experiment should under-report taxes. However, our results indicate that a large fraction of firms fully comply regardless of the imperfect monitoring. This, once again, is an indication that compliance behavior is determined by other factors besides what the standard models of economics of crime predict. Regarding the fraction of subjects underreporting taxes in each country, there are no statistical differences in the proportion of adopters and non-adopters underreporting when the monitoring probability is high, as shown in Table 9. However, the fraction of Swedish adopters violating the regulation is statistically lower when the monitoring probability is low.

Table 9: Non-parametric test of the proportion of subjects underreporting taxes in Colombia and Sweden

Group	Low monitoring probability (%)			High monitoring probability (%)		
	Colombia	Sweden	p-value	Colombia	Sweden	p-value
Adopters	71.43	45.00	0.054***	53.85	58.82	0.750
Non-adopters	94.74	76.58	0.130	73.08	75.00	0.873
p-value	0.044**	0.017**	---------	0.153	0.261	---------

(***) statistically significant at 1%, (**) statistically significant at 5%, (*) statistically significant at 10%.

When it comes to adoption rates, they are larger than expected in all cases, as shown in Table 10. The theoretical model predicts that the adoption rate does not vary with the monitoring probability. We do find evidence to reject this hypothesis for Colombia (p-value = 0.029), but not for Sweden (p-value = 0.591). When comparing between countries, the adoption rate in Colombia is significantly higher than in Sweden when the monitoring probability is low. This is an interesting finding considering that self-reported attitudes indicate that Swedish subjects are more positive toward technology. This cross-country difference can be explained by the fact that Sweden has a higher degree of technology adoption in general and therefore its population is more experienced in making adoption decisions and comparing the pros and cons of investing in a new technology. Hence, their behavior is more in line with the model of rational optimization suggested by Villegas-Palacio and Coria (2010). Indeed, the technology index per country (World Economic Forum 2005) places Sweden as one of the top 4 economies in terms of availability of technology per inhabitant (out of a sample of 101 countries over the world), while Colombia is found in 67th place.[11]

Table 10: Non-parametric tests of adoption rate in Colombia and Sweden.

Adoption rate	Expected rate	Low monitoring probability			High monitoring probability		
		Colombia	Sweden	p-value	Colombia	Sweden	p-value
	20%	65%	42%	0.020**	50%	38%	0.229

4.3 Influence of behavioral variables on our results – some regressions

In line with Cummings et al. (2009), our central hypothesis is that observed differences in behavior related to emission levels, the extent of violation, and the adoption decision across subjects in Sweden and Colombia are due to cultural factors. Table 11 presents the results of a Tobit model where the dependent variable is the emission level and the explanatory variables are variables related to the theoretical model (such as monitoring probability and the adoption status) and behavioral and socio-demographic variables such as risk aversion, gender, and importance assigned to the environment. We run the same model for Colombia and Sweden.

Table 11: Tobit models for emissions level in Colombia vs. Sweden

Independent variable	Colombia	Sweden
Adoption status	-1.947***	-3.079***
	(-7.37)	(-8.15)
Low monitoring probability	-0.004	0.504
	(-0.01)	(1.34)
Risk aversion	0.023**	-0.029
	(2.01)	(-1.45)
Gender (1 if male)	1.451	-1.650
	(1.54)	(-1.03)
Risk*Gender	-0.022	0.031
	(-1.36)	(1.15)
Importance of environment	0.329**	0.273*

[11] The technology index measures a country's technological readiness by using indicators as companies spending on R&D, the creativity of its scientific community, and personal computer and internet penetration rates.

	(2.29)	(1.80)
_cons	6.199***	8.053***
	(7.01)	(4.46)
Sigma	1.272***	1.721***
N	105	93

t statistics in parentheses
(***) statistically significant at 1%, (**) statistically significant at 5%, (*) statistically significant at 10%.

In line with the analysis above, the results indicate that adoption has a positive and statistically significant emission-reducing effect. This holds for subjects in both Colombia and Sweden. However, in Sweden the impact of adoption is higher than in Colombia. Gender does not have a statistically significant effect on emission levels. Furthermore, as predicted by the theoretical model, emissions are not affected by the monitoring probability. With regards to the importance assigned to the environment, it significantly reduces the level of emissions in both countries. We also find that risk attitudes have a significant effect on the level of emissions for the Colombian subjects, while for the Swedish subjects the effect of this variable is rather small and statistically insignificant. In order to test the null hypothesis that there are no significant differences between coefficients in our two samples, we perform a likelihood ratio test of such a hypothesis. We do find evidence to reject the null hypothesis (p value = 0.016), which is an indication of differences between subject pools.

With the aim of studying the extent of violation and its determinants in our samples, we run a Tobit model for the extent of violations. Table 12 shows the results. As explanatory factors we include adoption status, a dummy variable indicating whether the subjects are facing a low monitoring probability, and the interaction of these two variables. As behavioral and socio-demographic variables we include gender, risk aversion, guilt and shame when violating a regulation, and how strongly subjects agree with statements such as "Environmental regulations should not be violated in any situation" and "Environmental regulations should not be violated only because it is illegal." In line with the theoretical predictions, we find that adoption status does not have a statistically significantly effect on the extent of violation. As predicted by the traditional models of economics of crime and in line with previous experimental findings (Cummings et al. 2009), we find that a lower monitoring probability increases the extent of violation in both countries.

We find that in contrast to Swedish subjects, in the Colombian sample gender has a significant (at 10%) impact on the dependent variable. Females are less likely to violate the regulations. This may have an important relevance to policy in developing countries since gender inequality at the top management levels in developing countries might create an even greater problem of non-compliance. When one compares the rather high levels of gender equality in Sweden and the poor performance of Colombia (See rankings in Hausmann et al. 2010), we should expect a poorer performance in developing countries in terms of violations of environmental regulations. This might be explained by two possible factors that transcend the scope of our study: one, the well-documented higher levels of risk aversion in females could induce a higher expected cost of the sanctioning; or secondly, a less robust finding that females might have more environmental-oriented preferences than men.

Another element of importance in explaining behavior across cultures has to do with pro-social emotions such as shame and guilt. In contrast to Colombian subjects, in the Swedish sample the feeling of guilt when violating a regulation has a significant impact (at 10%) on the extent of violation, supporting our claim that social norms interact with regulations to explain the performance of environmental regulation. As in the previous model we also performed a likelihood ratio test to test the null hypothesis of equality in the coefficients between the Swedish and the Colombian sample, and did find evidence to reject the null hypothesis (p value = 0.035).

Table 12: Tobit models for extent of violation in Colombia and Sweden

Dependent variable: Extent of violation	**Colombia**	**Sweden**
Adoption status	-0.579 (-0.76)	-0.509 (-0.51)
Low monitoring probability	2.160*** (2.82)	2.017** (2.33)
Adoption * Low monitoring probability	-0.99 (-0.92)	-1.623 (-1.14)
Risk aversion	0.027 (1.14)	-0.044 (-1.18)
Gender (1 for males)	3.374* (1.74)	0.401 (0.13)
Risk*Gender	-0.052 (-1.56)	0.006 (0.13)
Guiltiness when violating in anonymity	-0.734 (-1.51)	-0.776* (-1.88)
Shame when violating in anonymity	0.406 (1.01)	0.263 (0.61)
Environmental regulations should not be violated in any situation	-1.193*** (-3.13)	-0.344 (-0.86)
Environmental regulations should not be violated only because it is illegal	-0.036 (-0.17)	-0.109 (-0.40)
For this person, it is very important to be rich	0.339 (1.57)	-0.148 (-0.51)
For this person, it is very important always to do the correct thing	-0.121 (-0.53)	0.174 (0.65)

_cons	5.064** (1.92)	6.439** (2.09)
Sigma	2.373*** (11.39)	2.945** (10.04)
N	105	93

t statistics in parentheses.
(***) statistically significant at 1%, (**) statistically significant at 5%, (*) statistically significant at 10%.

We also run a Probit model for the probability of adopting the new technology for each sample. As in the case of the previous regressions, we performed a likelihood ratio test to explore the hypothesis that the coefficients of the variables are not significantly different between the countries. We did not find evidence to reject the null hypothesis that both samples have the same coefficients, and therefore we can pool both countries. Table 13 presents the marginal effects for a Probit model on the probability of adopting the new technology for each country and for the pooled sample. As expected, a higher degree of risk aversion and a larger fixed cost of adoption have a significantly negative effect on the probability of adoption. Subjects who are more risk averse or bear a higher fixed cost of adoption are less likely to adopt the new technology. Moreover, the effect of the monitoring probability on the adoption decision is statistically insignificant when controlling for the effect of risk aversion, adoption costs, gender and the pro-technology index on adoption, which supports the hypothesis that the adoption rate does not depend on the monitoring probability.

Table 13: Probit model for the adoption decision. Marginal effects

Dependent variable: Adoption status	**Colombia**	**Sweden**	**Pooled sample**
Low monitoring probability	0.166 (1.54)	0.034 (0.31)	0.08 (1.05)
Risk aversion	-0.016** (-2.43)	-0.007 (-1.18)	-0.01** (-2.61)
Gender (1 for males)	-0.33 (-0.79)	-0.739* (-2.84)	-0.476* (-1.82)
Risk*Gender	0.005 (0.64)	0.012 (1.45)	0.007 (0.216)
Fixed adoption costs (Thousand COP)	-0.414*** (-4.87)	-0.267*** (-3.55)	-0.326*** (-5.82)
Pro-technology index	-0.007 (-0.46)	0.010 (0.73)	-0.004 (-0.39)
N	105	93	195

t statistics in parentheses.
(***) statistically significant at 1%, (**) statistically significant at 5%, (*) statistically significant at 10%.

5. Conclusions

The aim of this paper is to bring light to the discussion on the use of environmental taxes in developing countries and how the design of regulatory mechanisms should take into account how pecuniary incentives may interact with social norms emerging from societal values. For that purpose, we perform an experimental analysis comparing compliance behavior with emission taxes in Colombia and Sweden, two countries where there are existing formal tax-based environmental systems, but yet differing in their level of enforcement. Interestingly, self-reported attitudes toward compliance with regulations and environmental protection are not statistically different between the Swedish and Colombian subjects. Hence, if one could argue that these self-reported attitudes are a good proxy for intrinsic motivations and social norms, they would not differ markedly between Colombian and Swedish subjects.

Our results indicate that although social norms and intrinsic motivations may play an important role in explaining compliance, the role of traditional tools such as auditing probability remains significant. They also suggest that a higher aggregate level of compliance can be achieved through more stringent enforcement. In previous experiments conducted in Colombia where also an imperfect monitoring and sanctioning mechanism based on monetary penalties, Cardenas et.al (2000) and Rodriguez et.al (2008) show that indeed social norms would explain lower levels of violations of the environmental regulations, but under such weak enforcement, the decay in compliance would be detrimental for social efficiency, due to the problem of crowding-out of these social preferences. This has a clear policy implication for most developing countries as to look for ways to improve monitoring and enforcement, as well as to seek for complementarities instead of substitutability of monetary and non-monetary incentives to induce environmental compliance.

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