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# Honesty in Environmental Regulation

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**Abstract**
This paper analyzes the determination of the optimal environmental regulatory policy under imperfect competition when the firms differ in their polluting technologies and degree of honesty. We show that more honesty does not necessarily imply lower social losses. The effect of honesty in social welfare depends not only on the degree of honesty measured by the proportion of honest firms and their particular cost features but also on the industry structure.

## 1. Introduction

Since Becker (1968), most of the literature on regulatory enforcement, and particularly on environmental policy, has considered given the regulation and focused on the setting of the fines and the probability of monitoring to achieve maximum compliance. The basic model assumes that the firms must decide whether to comply or not with the regulation on the basis of expected compliance costs and penalties, and the monitoring agency, through its effort, influences the compliance decision. The simplifying assumptions of this basic model have been relaxed to incorporate more realistic behaviors in order to understand some observed stylized facts that the basic model is unable to explain.[1]

The traditional approach to model regulatory compliance considers that the firms behave strategically responding only to economic incentives while other motivation for compliance is excluded. Recent casual and empirical evidence suggest that firms may also be motivated by ethical considerations when issues like environmental protection are in place. Some firms, no matter their compliance costs, behave honestly. Ethical values of managers and employees or altruistic behavior may explain this conduct.[2] Environmental

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1 For an excellent survey of the basic model and its extensions, see Heyes (2000).

2 See, for example, Erard and Feinstein (1994).

honesty can be a good strategy when customers are environmentally conscious (Frey 1992) and also can make the firm more attractive to potential and current stockholders. Most of the literature on environmental regulation does not take into account honest behavior and its impact on the formulation of the regulatory policy and its enforcement. To the best of my knowledge, only Heyes (2001) and Bontems-Rotillon (1999) have focused on environmental honesty and its impact on the optimal regulatory policy.[3]

Heyes (2001) analyzed the perverse effects of honesty in regulatory contexts. Contrary to the intuition, he showed that a higher degree of honesty could be welfare reducing as the regulator's objective function was increasing for low values of honesty and decreasing for high values. In these cases, any attempt by the regulatory authorities to encourage honest behavior led to lower social welfare. In his model, the firms decide their levels of pollution and the regulator uses taxes to influence their decisions. The firms do not compete in the product market, although Heyes mentions that the introduction of competition in the product market ''enrich rather than to negate'' his insights. In this paper, we analyze if this assertion holds when honest and dishonest firms are rivals in the product market. We consider a simple model in which firms differ in their polluting technologies and degree of honesty. We assume that the firms are divided exogenously into honest and dishonest firms and therefore, the type of firm is not a strategic choice. A risk neutral regulator must choose the regulatory policy that minimizes compliance costs and environmental damages. The regulator faces a binary decision: regulating the industry or not, where regulation consists of adopting a non-polluting technology. Honest firms are compliant although the expected fine for no compliance is smaller than the cost of compliance. Dishonest firms behave as in the traditional economic analysis and compare the expected penalties for no compliance to the cost of compliance.

The existence of honest firms is, in itself, puzzling. However, the evidence of overcompliance in the context of environmental regulation has been extensively documented. Although the probability of inspections is low, compliance is observed most of the time. Harrington (1988) reconciled these facts by taking into account the dynamic features of the regulatory process. The enforcement agency benefits from the repeated interaction with the firms and some firms comply although the expected penalty is lower than the cost of compliance in each period. When the environmental agency is responsible for enforcing more than one regulation, Heyes and Rickman (1999) also show that compliance takes place even though there are no incentives to comply. By dealing with the firms, the agency increases the overall level of compliance as it is cheaper for some firms to comply with only one regulation than to face a lower expected fine for non compliance with each regulation. Voluntary overcompliance is also found by Arora-Gangopadhyay (1995). In a duopoly model in which consumers care for the environment and are willing to pay a higher price the cleaner the technology the firm uses, they show that one firm chooses a technology above the minimum clean standard.

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3 The issue of honesty has been considered in the literature on income tax enforcement, but changes in the degree of honesty do not have any impact on the optimal enforcement policy. See Graetz et al. (1986).

No matter how important the above results are, we still do not have a theory of honesty based on ethics and in which honest behavior results from ethical values. Although overcompliance results in the above models, in the end, this behavior is driven by economic incentives. In this paper, honest behavior is assumed from the beginning for a subset of firms and the analysis focuses on the comparative statics effects of changes in honesty in the regulatory policy.[4] The effect of honesty in social welfare depends not only on the degree of honesty measured by the proportion of honest firms but also on their particular cost features. We show that more honesty does not necessarily imply lower social losses. From a public policy perspective, efforts to induce more honesty can be counter-productive. Although presented in a simple framework, the results show that simple presumptions (the more honesty, the better) may not be valid under imperfect competition when honesty is taken into account. Nevertheless, there are also circumstances under which the more honesty, the better. Namely, an increase in the number of honest firms is desirable when the less efficient firms are honest.

We present the model in the next section and determine the optimal regulatory policy in section 3. Finally, some conclusions are presented.

## 2. The Model

Consider an oligopolistic $N$-firm industry producing a homogeneous good with zero marginal costs. The production process generates one unit of pollution per unit of output unless a pollution-reducing technology is used. There is available a clean technology (it generates no pollution) that increases the marginal cost by $c > 0$. A subset $n \leq N$ of firms is using a technology that increases the marginal cost by only $\lambda_l c$ but generates $1 - \lambda_l$ units of pollution per unit of output while the remaining $N - n$ firms use a high-cost technology that increases the marginal cost by $\lambda_h c$ and generates $1 - \lambda_h$ units of pollution.[5] Let $0 \leq \lambda_l < \lambda_h < 1$. Each unit of pollution causes a damage $d > c$.

A risk neutral regulator wants to minimize a social loss function given by the sum of production costs and pollution damage. The regulator must decide whether to regulate the industry or not. Regulation of the industry consists of adopting the clean technology. As the clean technology is more expensive, firms do not have incentives to comply with the regulation. The regulator can achieve full compliance if the expected marginal cost firms incur under no compliance is, at least, $c$. Let $m(\alpha)$ be the monitoring expenses when the regulator inspects the firms with probability $\alpha, \alpha \in [0, 1]$. We assume that $m'(\alpha) > 0$ and $m''(\alpha) > 0$ for $\alpha \in (0, 1)$. Also, $m(0) = 0, m'(0) = 0$ and $m'(\alpha) \to \infty$ as $\alpha \to 1$.

4 Product competition and environmental policy have been mainly analyzed from the perspective of determining the optimal taxes. See, for example, Kim-Chang (1993), Shaffer (1995), Simpson (1995), Katsoulacos and Xepapadeas (1995, 1996) and Lee (1999). As one referee has suggested, it would be interesting to explore the use of Pigouvian taxes in the presence of honesty to see if our results hold. An analysis in that direction is provided by Heyes (2001), who considered a regulatory regime based on taxes to reduce emissions when some firms were honest and found that more honesty was not always good from a social welfare perspective.

5 The $n$ firms are more efficient but pollute more.

Inspections reveal the technology the firms are using. Let $\bar{f}$ denote the maximum fine the regulator can levy per unit of output when an inspected firm does not comply with the regulation and is caught. We will assume throughout the paper that $c(1 - \lambda_h) > \bar{f}$. This assumption means that enforcing full compliance under regulation is unfeasible. In Appendix 2, we relax this assumption and show that the results, qualitatively, do not change.

Let $P = P(Q)$ be the inverse demand function, where $P$ is the market price and $Q$ is the aggregate output. We assume that $P(Q)$ is twice continuously differentiable with $P' < 0 \forall Q \geq 0$ such that $P(Q) > 0$. When the regulator decides to regulate the industry, he chooses the probability of monitoring and the fine for no compliance. Given a regulatory policy, the firms, after their compliance decisions,[6] select simultaneously their levels of output to maximize their profits. In order to guarantee the existence of a unique pure strategy equilibrium, we assume, following Gaudet and Salant (1991), that $P'(Q) + P''(Q)q_i < 0 \forall q_i, i = 1, \ldots, N$, where $q_i$ is the firm $i$'s output. Finally, in equilibrium, we require the output of each firm to be strictly positive.

The firms are exogenously divided into honest and dishonest firms.[7] Honest firms always comply with the regulation. Dishonest firms, given the above assumptions, do not comply. As we will see, this does not imply that the regulator never regulates the industry as monitoring affects the production decisions. The regulator knows the distributions of both the pollution-reducing technologies and honesty in the industry although he lacks this information on a specific firm. Let $s$ be the number of honest firms among the more efficient firms (those with the lower marginal cost). Let $m$ be the number of honest firms among the less efficient firms. The $N$-firm industry is defined by $\{n, s, m\}$ with $s \leq n$ and $m \leq N - n$. The optimal regulatory policy depends on the number of honest firms and their costs. In the next section, we characterize the optimal regulatory policy for two specific industry structures and analyze how the social loss function varies with honesty. All proofs are relegated to the Appendix 1.

## 3. The Optimal Regulatory Policy

Let us first consider an industry in which the more efficient firms are honest ($n = s$). Let the industry be defined by $\{n, n, m\}$. We have $n + m$ honest firms although their marginal costs differ. Let us suppose that the regulator does not regulate the industry. Firm $i$ chooses the level of output $q_i$ to maximize its profits:

$$\max P(Q)q_i - \lambda_k c q_i, \quad i = 1, \ldots, N, \tag{1}$$

where $k$ equals $l$ if firm $i$ is a low-cost firm and equals $h$ otherwise. Let $\bar{q}$ and $\underline{q}$ be,

6 When the regulator does not regulate the industry, the firms do not have to decide whether to comply or not. We assume that they use their respective technologies.

7 Being honest or dishonest is not a strategic decision by the firms.

respectively, the equilibrium levels of output of the low-cost and high-cost firms. From (1), we have:

$$P'(Q(n))\bar{q} + P(Q(n)) = \lambda_l c, \tag{2}$$

$$P'(Q(n))\underline{q} + P(Q(n)) = \lambda_h c, \tag{3}$$

where $Q(n) = n\bar{q} + (N - n)\underline{q}$ is the aggregate equilibrium output. Note that the low-cost firms produce more as their marginal costs are lower: $\bar{q} > \underline{q}$. The social loss function when the regulator does not regulate the industry is given by:

$$SL(n) = n\bar{q}[\lambda_l c + (1 - \lambda_l)d] + (N - n)\underline{q}[\lambda_h c + (1 - \lambda_h)d].$$

Each firm generates a loss of $\lambda_k c + (1 - \lambda_k)d$ per unit of output, $k = l,\ h$. Note that the low-cost firms generate more losses. We are interested in analyzing how the social losses change with honesty, where honesty in the industry is measured by the proportion of honest firms. We can have more honesty either if $m$ increases keeping $n$ constant or if $n$ increases keeping $m$ constant. Note that honesty increasing changes in $m$ do not cause any variation in social losses. Therefore, we focus on honesty increasing changes in $n$ and we consider $n \in [0, N - m]$ for a given $m > 0$.[8] It turns out that the more honesty, the worse. Intuitively, when the number of more efficient firms increases, total industry output is larger. However, the response of the aggregate output of the more and less efficient firms differs. We have two opposite effects. On the one hand, the less efficient firms produce less as they compete against a higher number of more efficient rivals. Thus, we have a lower number of less efficient firms, each of them producing a lower output. Therefore, their contribution to the total losses is reduced. On the other hand, although each more efficient firm produces also less, the increase in its number compensates the reduction in production and, in aggregate, their output is larger. This latter effect dominates as industry output is larger. As the low-cost firms generate more losses, it follows that social losses increase.

**Lemma 1:** *The social loss function SL(n) is strictly increasing in the number of low-cost firms.*

If the regulator decides to regulate the industry, only the honest firms comply.[9] Now, there are $n + m$ honest firms with a marginal cost of $c$ and $N - n - m$ dishonest firms with a (expected) marginal cost of $\lambda_h c + F$, where $F$ is the expected unit fine to be determined endogenously by the regulator. Let $\alpha$ be the probability of monitoring and $f$ the fine for no compliance. Let $q_e^r(\alpha,\ f)$ and $q_u^r(\alpha,\ f)$ be, respectively, the equilibrium output of an honest (ethical) and a dishonest (unethical) firm when the industry is regulated:

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8 An honesty-increasing change in $n$ transforms the industry $\{n, n, m\}$ into $\{n + 1, n + 1, m\}$.

9 The regulator, given the assumptions, is unable to enforce full compliance with the regulation. See Appendix 2 for the analysis when full compliance is feasible.

$$q_e^r(\alpha,\ f) = \arg\max[P((m+n)q_e + Q_u^r(\alpha,\ f)) - c]q_e,$$
$$q_u^r(\alpha,\ f) = \arg\max[P((N-m-n)q_u + Q_e^r(\alpha,\ f)) - \lambda_h c - \alpha f]q_u,$$

where $Q_u^r(\alpha,\ f) = (N-m-n)q_u^r(\alpha,\ f)$ and $Q_e^r(\alpha,\ f) = (m+n)q_e^r(\alpha,\ f)$ are, respectively, the equilibrium aggregate output of the dishonest and the honest firms. The social loss function under regulation is given by:

$$SL^r(\alpha,\ f, n) = cQ_e^r(\alpha,\ f) + (\lambda_h c + (1-\lambda_h)d)Q_u^r(\alpha,\ f) + m(\alpha).$$

The honest firms do not pollute although incur a cost $c$ per unit of output. The dishonest firms generate a damage $d$ per unit of output and incur a cost $\lambda_h c + \alpha f$. As fines are transfers from the firms to the regulator, they are not included in the social loss function. The regulator acts as a Stackelberg leader and chooses $(\alpha,\ f)$. The firms, taking as given the probability of monitoring and the fine, select simultaneously their levels of output. The regulator solves the following problem:

$$\begin{aligned} \min \quad & SL^r(\alpha, f, n) \\ \text{s.t.} \quad & \alpha \in [0,1] \\ & f \le \bar{f}. \end{aligned} \tag{P1}$$

Any expected fine $\alpha f$ with $f < \bar{f}$ can be achieved with a lower $\alpha$ by choosing the maximum fine $\bar{f}$. As monitoring is costly, it follows that the regulator always chooses the maximum fine. Although the regulator is unable to enforce full compliance, this does not mean necessarily the absence of monitoring. Monitoring increases the marginal cost of the dishonest firms, and affects not only to their production, but also to that of the honest firms. An increase of the probability of monitoring reduces the output of the dishonest firms, and also their levels of pollution and production costs. However, there is another effect that may argue for less monitoring. Honest firms increase their output and their aggregate compliance costs are larger. When the latter effect dominates, the regulator does not monitor the firms as monitoring is costly and more monitoring increases social losses. In the limit, when all firms are honest, the regulator does not monitor as all the firms comply with the regulation. Let us assume that $\partial SL^r(0, \bar{f}, 0)/\partial\alpha < 0$.[10] Given the assumptions on $m(\alpha)$, it follows that the optimal probability of monitoring $\alpha^*(n)$ satisfies the first order condition:

$$c\frac{\partial Q_e^r(\alpha, f)}{\partial\alpha} + (\lambda_h c + (1-\lambda_h)d)\frac{\partial Q_u^r(\alpha,f)}{\partial\alpha} + m'(\alpha) = 0,$$

i.e., $\alpha^*(n)$ is an interior solution for $P1$ for $n < N - m$.[11] Differentiating the first order condition yields:

10 For example, this assumption is satisfied when the inverse demand function is lineal.

11 Implicitly, we assume that the second order condition are satisfied.

$$\frac{d\alpha^*(n)}{dn} = \frac{\partial^2 SL(\alpha, f, n)/\partial\alpha\,\partial n}{\partial^2 SL(\alpha, f, n)/\partial\alpha^2}.$$

The second order conditions imply that the denominator is positive. Then, depending on the sign of the numerator, the optimal probability of monitoring may increase or decrease with honesty. Optimal losses are given by $SL^r(n) = SL^r(\alpha^*(n), \bar{f}, n)$. When honesty increases, the change in social losses is given by:

$$\frac{dSL^r(n)}{dn} = \frac{\partial SL^r}{\partial\alpha}\frac{d\alpha^*(n)}{dn} + \frac{\partial SL^r}{\partial n}.$$

By the envelope theorem, the first term on the right is zero, and therefore:

$$\begin{aligned}\frac{dSL^r(n)}{dn} = \frac{\partial SL^r}{\partial n} &= c\frac{dQ_e^r}{dn} + (\lambda_h c + (1-\lambda_h)d)\frac{dQ_u^r}{dn}\\ &= c\frac{dQ^r}{dn} + (1-\lambda_h)(d-c)\frac{dQ_u^r}{dn},\end{aligned}$$

where $Q^r$ is the aggregate output under regulation. It turns out that social losses are strictly decreasing in $n$. When $n$ increases, total marginal costs are higher as more firms comply with the regulation. Thus, industry output is lower. As before, the response of the honest and dishonest firms differs. It follows that the individual output of the honest firms $q_e^r$ increases with $n$, and therefore, $Q_e^r$ increases with $n$. It must be, then, that the aggregate output of the dishonest firms $Q_u^r$ decreases with $n$. When the regulator regulates the industry, the more honesty, the better. Although the output of each dishonest firm is now larger, their aggregate output is smaller and social losses are reduced. On the other hand, the aggregate compliance costs of the honest firms are larger, increasing social losses. However, this latter effect is dominated by the former, and social losses are reduced as honesty increases.

**Lemma 2:** *When the industry is regulated, the social loss function $SL^r(n)$ is strictly decreasing in n.*

The relationship between the social losses and honesty is different under both regulatory policies. When the regulator regulates the industry, an increase in honesty (a larger $n$) reduces social losses. However, when there is no regulation, social losses increase with honesty (Lemma 1). Given $n$ and $m$, the regulator chooses the regulatory policy for which social losses are lower. We have the following result.

**Proposition 1:** *Let the industry be defined by $\{n, n, m\}$. Assume that the regulator prefers not to regulate the industry when the number of honest firms is $m (n = 0)$ and prefers to regulate the industry when all the firms are honest $(n = N - m)$. Then, there exists a critical value $\tilde{n} \in (0, N - m)$ such that social losses increase with honesty for $n < \tilde{n}$ and decrease with honesty for $n > \tilde{n}$.*

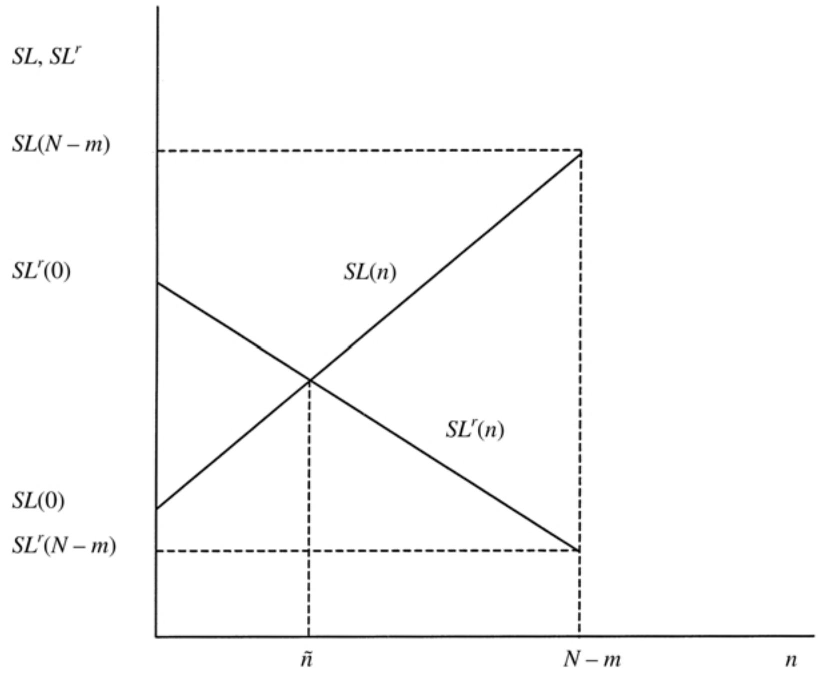


Figure 1. Optimal regulatory policy for an industry $\{n, n, m\}$.

The optimal regulatory policy as a function of $n$ is depicted in figure 1. We have drawn the social loss function when the regulator does not regulate the industry $SL(n)$. From Lemma 1, it is increasing in $n$. When the industry is regulated, the social loss function $SL^r(n)$ is decreasing in $n$. Social losses in the optimal regulatory policy are given by the lower envelope in the figure. For $n \leq \tilde{n}$, social losses are lower when the industry is not regulated. For $n > \tilde{n}$, the regulator prefers to regulate the industry as social losses are lower. We see that more honesty (a higher $n$) does not necessarily imply lower social losses. In particular, if for a given $n$ the optimal regulatory policy is not to regulate, then, increasing honesty leads to higher losses. Note that for this to happen, we require $SL(0) < SL^r(0)$. More honesty is better when the optimal policy is to regulate the industry. In that case, a larger $n$ implies lower losses. When $SL(0) \geq SL^r(0)$, regulation is optimal regardless of $n$ and the more honesty, the better. We should expect $SL(0) < SL^r(0)$ the closer $\lambda_h$ to 1. In the limit, $SL(0) = SL^r(0)$ as all firms have a marginal cost $c$. A marginal contraction in $\lambda_h$ has a negligible effect on production costs and pollution damage but, under regulation, we have to incur the monitoring expenses.

We focus next on a different industry structure to illustrate that the effects of honesty can be different than those shown in figure 1. Let us consider an industry in which the less efficient firms are honest ($N - n = m$). Let the industry be defined by $\{n, s, N - n\}$. We have $N - n + s$ honest firms although their marginal costs differ. When $n$ increases, the proportion of honest firms either decreases or remains the same.[12] As we are interested in the effects of honesty on the social losses, we focus on changes in $n$ that decrease honesty by keeping $s$ unchanged. Given $s > 0$, we focus on $n \in [s, N]$.

Under no regulation, the equilibrium outputs and the social loss function do not change. Therefore, the social loss function behaves as before when $n$ changes although, now, the more honesty, the lower the social losses. The social loss function is increasing in $n$, but honesty and $n$ are inversely related. When the industry is regulated, only the honest firms comply. Now, there are $N - n + s$ honest firms with a marginal cost of $c$ and $n - s$ dishonest firms with a (expected) marginal cost of $\lambda_l c + F$, where $F$, as before, is the expected fined to be determined endogenously by the regulator. The social loss function under regulation is given now by:

$$SL^r(\alpha, f, n) = cQ_e^r(\alpha, f) + (\lambda_{lc} + (1 - \lambda_l)d)Q_u^r(\alpha, f) + m(\alpha),$$

where $Q_e^r(\alpha, f)$ and $Q_u^r(\alpha, f)$ denote, as before, the aggregate output of the honest and dishonest firms. Now, the regulator solves a problem similar to $P1$. If we assume $\partial SL^r / \partial \alpha\,(0, \bar{f}, s) < 0$, then, for $n \in [s, N]$, the optimal probability of monitoring $\alpha^*(n) \in (0, 1)$. Optimal losses are given by $SL^r(n) = SL^r(\alpha^*(n), n)$. By the envelope theorem, we have:

$$\begin{aligned}\frac{dSL^*(n)}{dn} = \frac{\partial SL^r}{\partial n} &= c\frac{dQ_e^r}{dn} + (\lambda_l c + (1 - \lambda_l)d)\frac{dQ_u^r}{dn} \\ &= c\frac{dQ^r}{dn} + (1 - \lambda_l)(d - c)\frac{dQ_u^r}{dn},\end{aligned}$$

where $Q^r$ is the aggregate output under regulation. When $n$ increases, total marginal costs are lower. Thus, industry output is higher. By the same reasoning than in Lemma 1, it follows that $q_e^r$ decreases with $n$. Thus, $Q_e^r = (N - n + s)q_e^r$ decreases with $n$. It must be, then, that the aggregate output of the dishonest firms $Q_u^r$ increases with $n$. When the regulator regulates the industry, the social loss function is strictly increasing in $n$. The more honesty, the better. Although the output of each dishonest firm is now smaller, their aggregate output is larger and social losses are increased. On the other hand, the aggregate compliance costs of the honest firms are smaller, reducing the social losses. However, this latter effect is dominated by the former, and therefore, social losses are larger as $n$ increases.

When the structure of the industry is $\{n, s, N - n\}$, we have seen that social losses under both regulatory policies (regulation and no regulation) grow up with $n$. As the larger $n$, the less honesty, it follows that as honesty increases, social losses are reduced. We have the following result.

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12 An honesty-decreasing change in $n$ transforms the industry $\{n, s, N - n\}$ into $\{n + 1, s, N - n - 1\}$ or $\{n + 1, s - 1, N - n\}$.

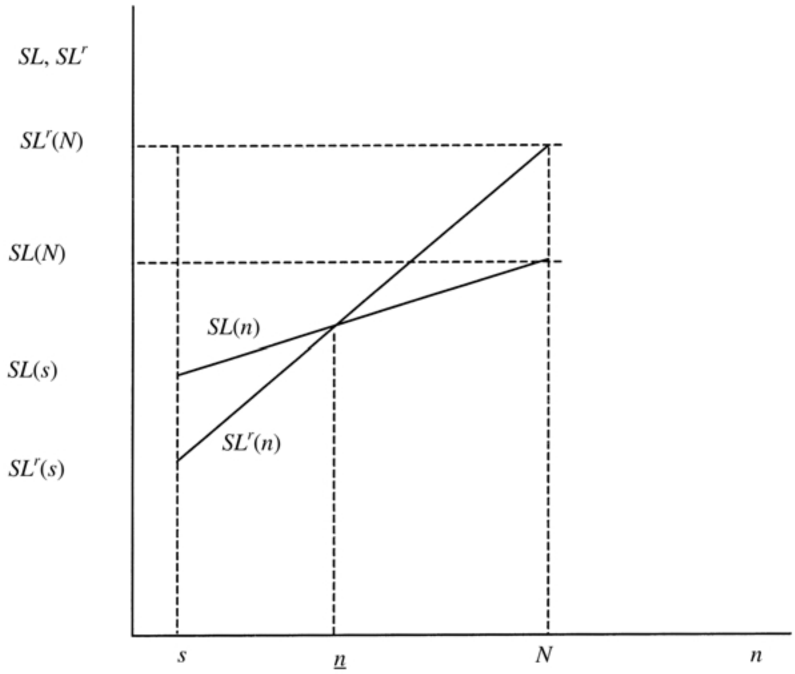


Figure 2. Optimal regulatory policy for an industry $\{n, s, N - n\}$.

**Proposition 2:** *Let the industry be defined by* $\{n, s, N - n\}$. *Then, regardless of the regulatory policy, an increase in honesty reduces social losses.*

In figure 2, we have depicted the optimal regulatory policy when $SL^r(s) < SL(s)$ and $SL^r(N) > SL(N)$. We have drawn the social loss functions under both regulatory policies. In this case, both functions are increasing in $n$. We see that the optimal regulatory policy depends on $n$. The regulator prefers to regulate the industry for $n \leq \underline{n}$ and not to regulate for $n > \underline{n}$, where $\underline{n}$ satisfies $SL^r(\underline{n}) = SL(\underline{n})$. In this case, the larger $n$, the lower the degree of honesty. Therefore, the more honesty, the better. Note that the optimal regulatory policy as a function of $n$ can be different than that shown in the figure if $SL^r(s) > SL(s)$ or $SL^r(N) > SL(N)$. However, the result that more honesty leads to lower social losses remains. This result contrasts with that found when the industry structure was $\{n, n, m\}$. So far, we have assumed that the firms in the subset $n \leq N$ are more efficient. The results are not affected qualitatively when these firms are less efficient. Let the industry structure be defined by $\{n, n, m\}$ where the less efficient firms (their marginal cost is $\lambda_h c$) $n$ are honest and the remaining $N - n$ firms (their marginal cost is $\lambda_l c$) are divided into honest $(m)$ and dishonest $(N - m - n)$. The analysis for this industry structure is qualitatively similar to that of the industry $\{n, s, N - n\}$ when the $n$ firms are more efficient. Therefore, the more honesty, the better.

Finally, let the industry be defined by $\{n, s, N - n\}$ where the more efficient firms $N - n$ are honest and the less efficient firms $n$ are divided into honest $(s)$ and dishonest $(n - s)$. In this case, the results are qualitatively similar to those found for the industry $\{n, n, m\}$ when the more efficient firms $n$ are honest. For this to happen, we require, like in Proposition 1, that the regulator prefers to regulate when $s = 0$ and not to regulate when $s = N$.

## 4. Conclusions

In this paper, we have analyzed the determination of the optimal environmental regulatory policy under imperfect competition when some firms behave honestly. We have considered different industry structures. Industries differ in the number of honest firms and their marginal costs. For the regulator, honest behavior is desirable as honest firms do not pollute. However, they incur higher marginal costs than those of the dishonest firms under regulation. The dishonest firms have a competitive cost advantage that implies a higher production and pollution damages. The regulator, through monitoring, can reduce the gap in marginal costs and affects aggregate production costs and pollution damages. On the other hand, under no regulation, all firms pollute although they have lower marginal costs. There are several effects taking place simultaneously what makes the comparison between the two scenarios (regulation and no regulation) not an trivial task.

The counterintuitive result that more honesty implies a lower social welfare does not hold when the firms compete in the product market and the firms that have access to a less polluting technology are all honest. In that case, the more honesty, the better. However, when the firms that use a more polluting technology are all honest, an increase in honesty may decrease social welfare. A sufficient condition for this to happen is that the social losses under no regulation when all the firms use a less-polluting technology be lower than those under regulation. Under no regulation, all the firms comply but some damage is generated as their technologies pollute. Under full regulation, the honest firms do not generate any damage but their costs are larger. On the other hand, the dishonest firms do not comply and generate larger damages. When all the effects are taking into account, the optimal regulatory policy depends on the number of firms that use the more polluting technology.

We must then be careful when analyzing the effects of honesty in regulatory contexts as these depend not only on the number of honest firms (the degree of honesty) and their particular cost features but also on the industry structure.

## Appendix 1

**Proof of Lemma 1:** We can write the social loss function $SL(n)$ as:

$$SL(n) = Q(n)D_h + \bar{Q}(n)(d - c)\Delta\lambda,$$

where $D_h = c + (1 - \lambda_h)(d - c), \Delta\lambda = \lambda_h - \lambda_l$ and $\bar{Q}(n)$ is the aggregate output of the low-cost firms. It suffices to show that both the industry output and the aggregate output of the low-cost firms increase as $n$ increases. Industry output in any interior equilibrium is related negatively to the sum of the constant marginal costs (Bergstrom and Varian 1985).

When $n$ increases, total marginal costs are lower. Thus, industry output is higher. From (3), as $n$ changes we have:

$$\left[P''(Q(n))\underline{q} + P'(Q(n))\right]\frac{\partial Q(n)}{\partial n} + P'(Q(n))\frac{\partial \underline{q}(n)}{\partial n} = 0.$$

Given the assumptions on $P(Q)$, it follows that $\partial \underline{q}/\partial n < 0, k = l, h$ as the industry output increases with $n$. As the aggregate output of the high-cost firms $(N - n)\underline{q}$ decreases with $n$, it must be that the aggregate output of the low-cost firms increases with $n$. ■

**Proof of Proposition 1:** Let $SL(0) < SL^r(0)$ and $SL^r(N - m) < SL(N - m)$. As $SL(n)$ is strictly increasing in $n$ and $SL^r(n)$ is strictly decreasing in $n$, there exist a $\tilde{n} \in (0, N - m)$ such that $SL(\tilde{n}) = SL^r(\tilde{n})$. For $n < \tilde{n}$, no regulation is optimal, and therefore, increases in $n$ cause larger social losses. For $n > \tilde{n}, SL(n) > SL^r(n)$ and regulation is the optimal policy. For this range of $n$, as social losses are decreasing in $n$, it follows that more honesty reduces social losses. ■

## Appendix 2

In the main text, we have assumed that enforcing full compliance with the regulation was unfeasible. In the following, we are going to relax this assumption. Let the industry be defined by $\{n, n, m\}$.[13] Let $\bar{\alpha} \in (0, 1)$ be such that $c = \lambda_h c + \bar{\alpha}\bar{f}$. The dishonest firms comply with the regulation for $\alpha \geq \bar{\alpha}$. The social loss function under regulation $SL^r(\alpha, n)$.[14] can be written as:

$$SL^r(\alpha, n) = \begin{cases} cQ^r(\alpha) + m(\alpha), & \text{if } \alpha \geq \bar{\alpha} \\ cQ_e^r(\alpha) + (\lambda_h c + (1 - \lambda_h)d)Q_u^r(\alpha) + m(\alpha), & \text{if } \alpha < \bar{\alpha}. \end{cases}$$

When all the firms comply with the regulation, there is no pollution and social losses are given by aggregate compliance costs plus monitoring expenses. When the honest firms only comply, social losses must include also the aggregate pollution damage generated by the dishonest firms. As monitoring is costly, social losses under full compliance are minimized for $\alpha = \bar{\alpha} \forall n$. Let us assume that $\lim_{\alpha \to \bar{\alpha}} m'(\alpha)$ is large enough to guarantee an interior solution $\forall n$ when the regulator minimizes social losses for $\alpha < \bar{\alpha}$. Let $\alpha^*(n) \in (0, \bar{\alpha})$ be the optimal probability of monitoring in that case. The regulator compares $SL^r(\bar{\alpha}, n)$ and $SL^r(\alpha^*(n), n)$ and chooses the probability of monitoring for which

13 The analysis when the industry structure is $\{n, s, N - n\}$ is qualitatively similar. It is available upon request.

14 The fine $f$ should appear as an argument in the social loss function. For the sake of notational simplicity, we have skipped this dependence to make the reading of the paper easier. Note that the optimal fine, as in the main text, is the maximum $\bar{f}$.

the social losses are lower. For the same reasoning than in the main text, $SL^r(\alpha^*(n), n)$ is decreasing in $n$. The smaller the number of dishonest firms, the lower the social losses under regulation when full compliance is not enforced. The social losses when full compliance is enforced $SL^r(\bar{\alpha}, n)$ do not vary with $n$. When $n \to N - m$, $SL^r(\alpha^*(n), n) < SL^r(\bar{\alpha}, n)$. Let us assume that $SL^r(\alpha^*(0), 0) > SL^r(\bar{\alpha}, 0)$: the regulator prefers to enforce full compliance when $n = 0$. Then, the optimal probability of monitoring under regulation $\alpha^r(n)$ is given by:

$$\alpha^r(n) = \begin{cases} \bar{\alpha}, & \text{if } n \leq \hat{n} \\ \alpha^*(n), & \text{otherwise,} \end{cases}$$

where $\hat{n}$ is the number of low-cost firms that makes the regulator indifferent between enforcing full compliance and no compliance. Thus, the social loss function under regulation is decreasing in $n$ for $n > \hat{n}$ and does not change for $n \leq \hat{n}$. It remains to determine the optimal regulatory policy. Given the assumptions of Proposition 1, it follows that we obtain the same qualitative results regarding the relationship between social losses and honesty. Recall that we defined $\tilde{n}$ as the number of low-cost firms such that the social losses for both regulatory policies (no regulation and regulation) coincided. We distinguish two cases. When $\hat{n} \leq \tilde{n}$, the optimal regulatory policy for $n \leq \tilde{n}$ is no regulation. For $n > \tilde{n}$, the regulator prefers to regulate the industry, although regulation does not achieve full compliance. When $\hat{n} > \tilde{n}$, the optimal regulatory policy for $n \leq \tilde{n}$ is no regulation. For $n \in (\tilde{n}, \hat{n}]$, the regulator regulates the industry and enforces full compliance. For $n > \hat{n}$, the industry is regulated but the regulator does not pursue full compliance. Regardless of the relationship between $\hat{n}$ and $\tilde{n}$, it follows that more honesty does not lead necessarily to lower social losses.

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