Design and Enforcement of Legal Standards

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Abstract: Laws are costly to enforce. We explore the implications of this principle in a model where the design of the laws and their enforcement are determined jointly. A benevolent government trades off the benefit of a stricter legal standard with the cost of its enforcement. Therefore, legal standards and enforcement are complements, and increase in aggregate wealth. If bureaucrats are corruptible, the optimal legal standard is lower. With a self-interested government legal standards may be increasing in corruption, according to the "toll-booth view". International evidence on environmental regulation shows that standards are correlated positively with enforcement and negatively with corruption.

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"Rights cannot be protected or enforced without public funding ... A theory of rights that never descends from the heights of morality into the world of scarce resources will be sorely incomplete" (Holmes and Sunstein, 1999. pp. 15 and 18).

1 Introduction

Starting with the seminal contributions by Becker (1968) and Stigler (1970), a substantial body of literature has investigated the optimal enforcement of laws (see Polinsky and Shavell, 2000, for a recent survey). These contributions take the law to be enforced as given. However, the design of a law should consider the question of enforcement. Stricter and more complex laws require more incisive and costlier enforcement machinery. We explore the implications of this point, using a model in which enforcement and legal standards are jointly determined.

Since in our analysis the design of the law – not merely its enforcement – is endogenous, we consider an economy in which there is a rationale for a law, in the sense that it can remove a market inefficiency. The specific market failure that we consider arises from a moral hazard problem. Because product quality is unobservable, in the absence of regulation producers would choose an inefficiently low quality level. Governments can remedy the problem, imposing a minimum quality level by law. However, to enforce the legal standard it must allocate resources to detect and punish violators. The stricter the standard, the greater the incentive to evade the law, and therefore the greater the amount of resources that must be spent on enforcement. Spending on enforcement, being funded via taxation, reduces the amount of consumption that people can afford.

A benevolent government must balance the resource cost of enforcement against the benefit from higher product quality. As a result, the second-best quality level is lower than the first-best. Moreover, the strictness of the optimal legal standard increases with aggregate wealth. Poorer countries cannot afford high enforcement costs, and therefore must set lower standards. The standard also depends on the effectiveness of enforcement technology: countries with costlier enforcement should adopt less ambitious standards. Finally, the level of the standard should rise with the value that consumers assign to product quality. A case in point is the increasing demand for regulatory standards for computer software reliability, as society becomes more dependent on software in its everyday life.[1]

When there is a risk that bureaucrats may take bribes from non-compliers, the standard

[1] According to Charles C. Mann (2002), "computers have become so essential to daily life that society will eventually be unwilling to keep giving software firms a free legal pass. 'It's either going to be a big product liability suit, or the government will come in and regulate the industry,' says Jeffrey Voas, chief scientist of Cigital Labs, a software testing firm" (p. 38).

should be set even lower than in the absence of corruption, in order to weaken the incentive to collude. In a sense, corruption can be seen as a lowering of enforcement effectiveness. So, if governments are benevolent, countries with more corruptible bureaucracies should feature lower legal standards.[2] This result parallels that obtained by Acemoglu and Verdier (2000), who show that government intervention is limited by the corruptibility of bureaucrats. As in our model, this result derives from the fact that corruption raises the resource cost of the enforcement: in Acemoglu and Verdier's framework, this additional cost takes the form of higher salaries to incentivize bureaucrats, while in our model it takes the form of higher monitoring costs. The main difference is that in our analysis the additional cost of corruption affects also the design of the law, not only the strictness of its enforcement.

However, the rot may extend beyond the officials entrusted with enforcing the law: it may involve also those who draft it. Regulators themselves may be self-interested in designing regulatory standards. Indeed, one strand of the literature – the "tollbooth view" – maintains that governments design the regulations in such a way that bureaucrats and politicians can collect bribes from producers.[3] Djankov, La Porta, Lopez-de-Silanes and Shleifer (2002) apply this thesis to the regulation of entry, showing that the severity of the rules correlates positively with corruption in a cross-section of countries. To take this possibility into account, we extend our model to the case in which the government attaches a positive weight to the bribes that its officials can extract, and interpret this weight as the degree of self-interest of the government. We find that if bribes are extracted at all, a more self-interested government will set a stricter standard and extract more bribes, consistent with the "tollbooth view". However, when governments that do extract bribes are compared with those that do not, these comparative statics become ambiguous. The former may choose either a lower or a higher legal standard.

Our setting can also be re-interpreted as a model of optimal environmental standards. This re-interpretation allows us to test its predictions using international data on environmental regulation and enforcement. The evidence is consistent with several predictions. For instance, the strictness of regulation appears to be positively correlated with the resources devoted to its enforcement. Empirically, environmental standards appear to be negatively correlated with measures of corruption. Thus, the descriptive evidence squares with the benevolent government, rather than the "tollbooth view" model.

In this paper we consider no mechanisms other than government regulation, such as entrusting quality standards to a private agency, i.e. self-regulation. However, DeMarzo,

[2] This problem is analyzed also in the literature on optimal regulation under asymmetric information and regulatory capture (Laffont and Tirole, 1993).

[3] Early statements of this view can already be found in the work of Rose-Ackerman (1978).

Fishman and Hagerty (2001) show that if the self-regulatory organization is mandated to maximize the welfare of its members, it chooses laxer enforcement than customers would choose. Alternatively, in a dynamic setting, the producers' moral hazard may be tempered via reputation-building in a context of repeated interaction. But to be effective, such reputational mechanisms require substantial communication among consumers, ensuring that deviations from the pledged level of quality trigger effective punishment.

The paper is organized as follows. Section 2 lays out the model and shows that in the absence of a legal standard the competitive equilibrium is inefficient. Section 3 characterizes the design and enforcement of the legal standard by a benevolent government and also examines how the standard is affected by the agency problem created by corrupt bureaucrats. Section 4 extends the model to the case of a self-interested government. Section 5 presents a public-good reinterpretation in which the legal standard refers to environmental regulation. Based on this reinterpretation, in Section 6 we test the model's predictions using cross-country data about environmental regulation and enforcement. Section 7 concludes.

2 The Model

In this section we illustrate the basic idea in terms of the relationship between the buyer and the producer of a "quality good", i.e., an object whose quality is not observed by the buyer but affects his valuation of the good. Here, in contrast to Akerlof (1970), the quality of the good is chosen not by "nature" but by the producer, and it is not observable by the government except via the costly enforcement of a minimum standard. Therefore, we have a moral hazard problem with costly monitoring between the government and the producer.

The idea is more general than this setting may suggest. It concerns any economic relationship between two parties in which there is asymmetric information and the government can ameliorate the outcome of the exchange by setting and enforcing a minimum quality standard. It also applies to a public-good problem, where government standard-setting can improve the market allocation. In section 5 our setting is shown to be equivalent to a model of environmental standards.

2.1 Firms

The quality good is produced by identical firms, uniformly distributed on the unit interval. Firms operate under constant returns to scale and compete à la Bertrand. The profit from selling a unit of the good is a function of its quality, because this affects both the price that consumers are willing to pay and the production cost. The expression for profits is $\pi = v(q) - c(q;k)$, where $v(q)$ is the unit price of a good of quality q and $c(q;k)$ is its cost.

The cost function is increasing and convex in q, while k is a cost parameter. For brevity, from now onwards we shall write it as $c(q)$. The market game is one-shot: we do not consider repeated sales.

It should be noticed that, though one-dimensional, the quality measure q can be thought of as a summary measure of many different dimensions of "quality". For instance, in the case of chicken, it could be a synthetic index of the quality of chicken feed, of the preservatives present in the meat, of the method used to raise them (free-range or not), etc. This implies that a producer can raise the quality q either by raising the value of one of its particular components, such as the amount of preservatives (the "intensive margin" of quality) or by adding a new, previously neglected component, say the chemicals used to clean carcasses (the "extensive margin" of quality). By the same token, a regulator can mandate higher standards either by imposing more stringent criteria along given dimensions (a "stricter" law) or by increasing the number of parameters considered (a more "complex" law).

2.2 Consumers

The utility function of the representative consumer is defined over the consumption of two goods: a continuous and homogeneous good x and the quality good. All magnitudes are measured in units of the homogeneous good (hereafter, the "numeraire"). The consumer must demand a single unit of the quality good and a non-negative amount of the numeraire. His utility is:

$$U = x + u(q;\theta) \tag{1}$$

where $u(q;\theta)$, the utility drawn from the quality good, is increasing and concave in q, while θ is a taste parameter. For brevity, we shall write the utility function as $u(q)$.Therefore, the demand for this good is elastic in the quality dimension but inelastic in the quantity dimension: the price the consumer is willing to pay for it depends on q, while the quantity is fixed at 1 unit. For instance, the consumer buys a single car, but what he will pay depends on its quality.

The consumer's budget constraint is

$$x + v(q) \leqslant y + \pi - t \tag{2}$$

where the expression on the left-hand side is the consumer's total spending, y is his (positive) initial endowment, and t is the net tax burden (taxes minus transfers). In the context of the model, taxes are levied only to pay for the cost of enforcement, so in the absence of public intervention $t = 0$.

2.3 Equilibrium without Public Intervention

It is easy to show that if quality is observable, the first-best allocation coincides with a Nash equilibrium with Bertrand competition. The first-best allocation is found by maximizing expression (1) with respect to x and q, subject to the budget constraint (2) and to the zero-profit condition:

$$\pi = v(q) - c(q) = 0, \tag{3}$$

since this is equivalent to maximizing social welfare:

$$\max_{q} \; W = y + u(q) - c(q). \tag{4}$$

The necessary and sufficient condition for welfare maximization is:

$$u'(q) = c'(q). \tag{5}$$

The value of q that solves (5) is the first-best (FB) level of quality q^{FB}. We denote the corresponding level of social welfare by W^{FB}.

This allocation coincides with the Nash equilibrium of an extensive-form game, where firms choose the quality q of the good they will produce and a price function $v(q)$. The strategy of firm j is a vector $s_j = (q_j, v(q_j, q_{-j}))$, where q_{-j} is the vector of qualities chosen by all competing firms. Consider the equilibrium candidate where all firms choose the first-best quality and price $(q^{FB}, v(q^{FB}))$. This is a Nash equilibrium, since no firm can profitably deviate.[4]

Now let us consider the opposite scenario, in which product quality is unobservable. We assume that producers cannot offer a quality guarantee, because it is too costly for consumers to verify. For instance, it would be prohibitively expensive for a consumer to check whether a chicken in the supermarket was raised with hormones or whether it is free-range, or whether the electromagnetic waves of a portable phone exceed a safety threshold.

In this case, firms set quality at its minimum level: $q = 0$. No positive level of quality is an equilibrium: if consumers expect this level, any firm that deviates by providing lower quality will make profits, as in Akerlof (1970). In the next section we show that such market failure can be tempered by an appropriate legal standard.

[4] There are three possible deviations. First, choosing a different quality $q_j \neq q^{FB}$ and $v_j = v(q^{FB})$ is not a profitable deviation since $q_j > q^{FB}$ implies losses, while $q_j < q^{FB}$ implies zero demand. Second, setting a different price $v_j \neq v(q^{FB})$ and $q_j = q^{FB}$ implies losses if $v_j < v(q^{FB})$ and zero demand if $v_j > v(q^{FB})$. Finally, no firm will choose to deviate by setting both a price $v_j \neq v(q^{FB})$ and a quality $q_j \neq q^{FB}$. If all other firms offer the first-best quality and price, no consumer will accept a combination of price $v_j \neq v(q^{FB})$ and quality $q_j \neq q^{FB}$ such that firm j makes zero profits, by the very definition of a first-best allocation. A fortiori, no consumer will accept a combination of price $v_j \neq v(q^{FB})$ and quality $q_j \neq q^{FB}$ such that firm j makes positive profits.

3 Intervention by a Benevolent Government

If the government's objective is to maximize social welfare, it can intervene to attenuate the market failure described above and promote quality. The government has two roles. First, it designs the law and the penalty for infringement. Second, it determines the resources to allocate to enforcement.

The law thus consists of a minimum quality standard s and a penalty function $l(q, s)$ setting the liability of violators. We assume that the penalty is monetary and cannot exceed an upper bound $\bar{l}$. Limited liability implies that $\bar{l} \leqslant y - t + \pi$.[5]

[Insert Figure 1]

Figure 1 illustrates the sequence of moves. First, the government chooses standard s and the level of enforcement resources e. Then, firms choose the quality level of their output, q. Next, bureaucrats enforce the standard by inspection, detecting non-compliance with probability $p(e; h)$, where h is a parameter that captures the technical efficiency of enforcement.[6] Finally, consumers buy the good at a price that reflects its average quality.

The technology of enforcement has decreasing marginal productivity. That is, the probability p is increasing and concave in effort: $p'(e; h) > 0$ and $p''(e; h) < 0$, with $\lim_{e \to 0} p'(e; h) = \infty$. For brevity, we shall write the detection probability as $p(e)$.

The firm's expected liability is $L = p(e)l(q, s)$. Thus with government intervention, expected profits become

$$\pi = v(q^E) - c(q) - L. \tag{6}$$

The quality good's price v depends on the quality expected by consumers, q^E, while its cost c to the producer depends on the actual quality level, q. The penalty L contributes to the government's revenue from penalties, $p(e)$ also being the fraction of firms that are inspected. Enforcement is costly and is financed out of the sum of net taxes and revenue from penalties (although, as we shall see below, no revenue from penalties is collected in equilibrium).[7]

[5] The model could accommodate a non-monetary sanction, for instance imprisonment. The social cost of imprisonment should then be accounted for in the expression for social welfare. In this case, the optimal monetary sanction is always maximal, as in our model (see below), but the non-monetary sanction may not be set at the maximal level (Shavell, 1991). However, our results concerning the relationship between standards and enforcement would be qualitatively unchanged.

[6] In our setting, the government precommits to the probability of detection $p(e, h)$ by alloting the level of resources e to enforcement activity. One can think of e as the salaries paid to policemen: once hired, each policeman detects violations with a technologically given probability.

[7] Since utility is linear in x, we are assuming lump-sum taxation. However, distortionary taxes would not change our qualitative results. The main difference would be that, by making enforcement more costly, tax distortions would lower the optimal standard compared to lump-sum taxation.

Assuming for simplicity that a unit of enforcement costs a unit of the numeraire good, the government budget constraint reads as

$$e = t + L. \tag{7}$$

3.1 Design and Enforcement of the Law

Since firms earn zero profits, a benevolent government will maximize the utility of consumers over the consumption x, the quality standard s, the enforcement level e and the penalty l:

$$\max_{x,s,e,l} U = x + u(s)$$

subject to the incentive constraint

$$v(s) - c(s) \geqslant v(s) - c(q) - L(e, q, s, l), \ \forall q \neq s \tag{8}$$

and to the feasibility constraints

$$x + e + c(s) \leqslant y, \tag{9}$$

$$x \geqslant 0. \tag{10}$$

The feasibility constraint (9) derives from the consumer's budget constraint (2), the government's budget constraint (7) and the definition of profits (6). Together with the non-negativity constraint (10), it ensures that the resources devoted to enforcement do not exceed the entire endowment ($e \leqslant y$). Since by optimality (9) is binding, we can rewrite the problem as the maximization of the social surplus subject to the incentive constraint and the feasibility constraint (10):

$$\begin{cases} \max\limits_{s,e,l} W = y + u(s) - c(s) - e, \\ \qquad \text{subject to (8) and (10)} \end{cases} \tag{11}$$

Becker (1968) shows, for any positive enforcement level it is optimal to set the penalty at the maximum feasible level: $l = \bar{l}$ if $e > 0$. Suppose in fact that $l < \bar{l}$. Then l could be raised and e lowered while keeping L constant. The social surplus $u(s) - c(s)$ in the objective function would be unchanged but the enforcement cost e would be lower, so that welfare W would be higher, contradicting the optimality of l.

Now we turn to the analysis of the optimal standard and enforcement level. First, from the incentive compatibility constraint and the enforcement technology, we get the level of enforcement e necessary to impose any quality standard s. The following lemma underscores the complementarity between enforcement and legal standards:

Lemma 1 (Complementarity between Standard and Enforcement) *The enforcement level e required to impose a quality standard s is the increasing and convex function $e(s) = p^{-1}\left(c(s)/\bar{l}\right)$.*

Proof. See Appendix A.

Higher standards require more spending on enforcement. By raising the production cost for firms, a stricter standard increases the incentive to deviate and thus requires more intensive enforcement. Enforcement resources must increase more than proportionately to the standard, due to the decreasing returns to enforcement activity (the concavity of $p(\cdot)$).

This intermediate result allows us to reformulate problem (11) in terms of s only and to drop the incentive constraint (8). The following proposition characterizes the resulting optimal standard s^*:

Proposition 1 (Characterization of the Optimal Standard) *The optimal quality standard s^* is positive but is lower than the first-best quality level q^{FB}. It is increasing in the maximum penalty $\bar{l}$ and weakly increasing in the endowment y.*

Proof. See Appendix A.

The proposition indicates that a minimum quality standard is always warranted. However, the government will not set the standard at the first-best level. The intuitive reason is that enforcement is costly and the proposition takes enforcement into account. This is made clear by the first-order condition that determines the optimal policy:

$$u'(s^*) = c'(s^*)\left[(1+\lambda)\left(1+e(s^*)\right)\right].$$

In this expression, λ is the subjective premium that the consumer household places on a dollar of the numeraire good whose consumption is forgone, and $e(s^*)$ is the optimal enforcement. The first-best quality would obtain if $\lambda = 0$ (the household has enough resources to consume both goods) and $e(s^*) = 0$ (enforcement is not needed). With unobservable quality, however, the term in square brackets exceeds 1 (because $e(s^*) > 0$ and $\lambda \geqslant 0$), and the concavity of $u(s)$ implies an optimal standard below the first-best. The shortfall of the optimal standard below first-best quality increases with the cost of enforcing the standard $e(s^*)$. A higher maximum penalty $\bar{l}$ decreases the enforcement cost $e(s^*) = p^{-1}\left(c(s^*)/\bar{l}\right)$ and thereby brings the standard closer to the first best. Similarly, the standard gets closer to the first best if the shadow value of income λ decreases: the richer the community, the higher the optimal standard it can afford.[8]

[8] In standard principal-agent theory, this result emerges directly from limited liability: wealthier agents can be punished more harshly, and therefore prodded to exert more effort. In our setting, the mechanim is more roundabout: greater wealth implies more tax revenue, which funds increased enforcement activity, which in turn sustains a higher standard.

[Insert Figure 2]

Figure 2 illustrates the equilibrium quality with government intervention. The convex function $e(s)$ shows the minimum enforcement required for each standard (from Lemma 1). The function is bounded above by the feasibility constraint, which is decreasing and convex, as can be seen by differentiating (9). The government's preferences are described by a field of concave, upward-sloping social indifference curves, from the properties of the welfare function $W(e,q)$: their slope $u'(q) - c'(q)$ is positive for quality levels lower than the first best $\left(q^{FB}\right)$, and is decreasing by the concavity of $u(q)$ and the convexity of $c(q)$.

Figure 2 can be used also to investigate how the optimal quality standard s^* responds to changes in consumers' taste for quality θ, enforcement efficiency h and firms' technical cost parameter k. Assume that each of these parameters increases the marginal value of the corresponding function in its entire domain: that is, an increase in θ raises $u'(q)$, $\forall q$. This assumption is satisfied, for instance, if these parameters enter multiplicatively in the respective functions: $u(q;\theta) = \theta u(q)$.

In the upper graph in Figure 2, the feasibility constraint is not binding ($\lambda = 0$) and the optimal values of e and s are at the tangency between the lowest indifference curve and the $e(s)$ function. Higher efficiency of enforcement h decreases the level and the slope of the $e(s)$ function and therefore shifts the tangency point to the right. In contrast, a higher cost parameter k shifts the tangency point to the left, because the $e(s)$ function steepens and the social indifference curves flatten. A larger endowment y shifts the feasibility constraint upward, leaving the equilibrium unaffected.

The lower graph in Figure 2 portrays a situation where the feasibility constraint is binding ($\lambda > 0$) . The second-best that corresponds to the tangency point cannot be achieved, because income y is insufficient to enforce the second-best quality level. In this situation, the entire income is spent on the quality good. The resulting constrained quality standard corresponds to the intersection between $e(s)$ and the feasibility constraint. In this case, a larger y moves the feasibility constraint upward, so that the intersection with the $e(s)$ function moves to the right and quality rises. The other comparative statics results are qualitatively identical to the previous case. Since an increase in the efficiency of enforcement h flattens the $e(s)$ function, it shifts the intersection with the feasibility constraint to the right, raising the optimal quality standard. An increase in the cost parameter k has the opposite effect: it steepens the $e(s)$ function and tilts the feasibility constraint clockwise.

These comparative statics can be summarized in this corollary:

Corollary 1 (Comparative Statics) *The optimal quality standard s^* is increasing in the consumers' marginal taste for quality and in the marginal efficiency of enforcement, and it* *is decreasing in the firms' marginal cost.*

3.1.1 An Example

To illustrate the results obtained so far, consider the case where the utility function is linear and the cost function is quadratic in the quality level:

$$U = x + \theta q,$$
$$c(q) = \frac{kq^2}{2},$$

with $\theta > 0$ and $k > 0$. In this example, the first-best level of equation (5) is $q^{FB} = \theta/k$ and the corresponding level of the social surplus is $W^{FB} = y + \theta^2/2k$.

When quality is unobservable, we assume that the probability of detection is linear in enforcement effort, that is:

$$p(e) = he,$$

with $h > 0$ and $e \in (0, 1/h)$.

The maximization problem (11) becomes:

$$\begin{cases} \max\limits_{s,e,l} \; W = y + \theta s - ks^2/2 - e, \\ \text{IC: } ks^2/2 \geqslant kq^2/2 - hel, \; \forall q \neq s, \\ \text{F: } \; x \equiv y - ks^2/2 - e \geqslant 0, \end{cases} \tag{12}$$

where IC and F indicate the incentive and the feasibility constraints.

Applying Lemma 1 to this example, one finds that the enforcement level e required to impose a given quality standard s is:

$$e(s) = \frac{k}{2h\bar{l}} s^2, \tag{13}$$

reflecting the fact that stricter laws require higher spending on enforcement.

To solve the above maximization problem, in this example we follow a constructive approach that differs from that used in the proof of Proposition 1. First we consider the parameter region where the feasibility constraint (F) is not binding ($x > 0$), when y is sufficiently large, then the region where (F) is binding ($x = 0$). These two cases correspond to the situations described in the two panels of Figure 2.

In the first case, the optimal legal standard s^* is found by maximizing the objective function W with respect to s, after replacing $e(s)$ from (13) and setting $q = s$. The second-best legal standard, enforcement level, numeraire consumption and social surplus are respectively:

$$s^* = \frac{\theta}{k}\frac{h\bar{l}}{1+h\bar{l}}, \quad e^* = \frac{\theta^2}{2k}\frac{h\bar{l}}{(1+h\bar{l})^2}, \quad x^* = y - \frac{\theta^2}{2k}\frac{h\bar{l}}{1+h\bar{l}}. \quad W^* = y + \frac{\theta^2}{2k}\frac{h\bar{l}}{1+h\bar{l}}. \tag{14}$$

This illustrates that s^* and W^* are smaller than q^{FB} and W^{FB}, respectively. The strictness of the law s^* and the enforcement level e^* (as well as the surplus W^*) are increasing in the private valuation of quality θ, the maximum penalty $\bar{l}$ and the efficiency of enforcement h, and are decreasing in the cost parameter k.

From the previous expression for x^*, the feasibility constraint (F) is seen to be binding for $y \leqslant \theta^2 h\bar{l}/[2k(1+h\bar{l})]$. In this second case, it must be that $x^* \equiv y - ks^2/2 - e = 0$, so that the constrained second-best quality standard is:

$$s^*(y) = \sqrt{\frac{2y}{k}\frac{h\bar{l}}{1+h\bar{l}}}. \tag{15}$$

In contrast with the previous case, here the quality standard is a function of y: wealthier communities can afford more stringent legal standards. However, the standard will be positive for any society with positive endowment ($s^* > 0$ for $y > 0$). It will be maximal for $y \geqslant \theta^2 h\bar{l}/[2k(1+h\bar{l})]$: for values of the endowment equal to or higher than this threshold, $s^*(y)$ achieves the second-best level of equation (14), s^*.

[Insert Figure 3]

Taken together, the expressions for the second-best legal standard in equations (14) and (15) describe how legal standards vary with the wealth of nations. As is shown graphically in Figure 3, the legal standard increases with national income until y reaches the threshold value $\theta^2 h\bar{l}/[2k(1+h\bar{l})]$. For values of y above this threshold, the legal standard stays constant at a value lower than the first-best, θ/k.

3.2 The Effect of Corruption

So far we have assumed enforcement of the legal standard to be implemented by honest officials: given a certain level of effort e chosen by the government, the probability of detection is determined by a purely technical relationship $p(e)$. However, there may be agency problems within the bureaucracy assigned to enforce standards. When officials can be bribed to be lenient, within our model entrepreneurs may have the incentive to do so and lower the quality of their product.

A simple way to capture this point is to assume that the government chooses the amount of resources assigned to officials, but cannot perfectly control their effort in enforcing the law. It can, however, devote some resources to policing their behavior via a layer of internal controls. We assume that these internal controls are performed by upper-tier functionaries who cannot themselves be corrupted (otherwise we have face an infinite recursion). Both layers of bureaucracy require resources: we denote by e_1 the resources allocated to lower-tier officials and by e_2 those allocated to the upper tier. As before, the total amount devoted to enforcement is raised via taxation: $e_1 + e_2 = t$.

Due to the agency problem within government, the probability of punishing delinquent firms depends not only on the probability of detecting them, $p(e_1)$, but also on the lower-tier officials' decision to report the misdemeanor or to omit the report in exchange for a bribe. Upon detection, a non-complying firm will agree to pay a bribe to avoid the penalty $\bar{l}$. The precise amount of the bribe is determined by the relative bargaining power of the official and the firm, but is inessential to our results.

The probability that an upper-tier official will detect a corrupt subordinate is an increasing function of the resources allocated to internal controls, $\alpha(e_2)$. If a corrupt official is detected, he is subjected to a monetary penalty P, which he pays out of his endowment. Therefore, to decide whether to accept or refuse a bribe, he will compare the bribe B with the expected cost of being punished by his superiors, $\alpha(e_2)P$. When a corrupt bureaucrat is detected, the corresponding firm is charged the penalty $\bar{l}$.

Figure 4 illustrates the sequence of moves, amending the time line of Figure 1 to include the corruption subgame, which begins after firms have already chosen their quality level q but consumers have not yet bought the good.

[Insert Figure 4]

Let us now consider the fourth stage of the game, when delinquent firms and officials may agree on a bribe. A lower-tier official accepts the bribe if it is larger than the expected penalty: $B > \alpha(e_2)P$. Going backward, a firm will offer the bribe if the penalty $\bar{l}$ that it would pay if reported exceeds the bribe B plus the expected penalty $\alpha(e_2)\bar{l}$ inflicted if the bribe is discovered. Therefore, the bribe is advantageous for the firm if $\bar{l} > B + \alpha(e_2)\bar{l}$. Putting these two conditions together, corruption is a strictly dominant strategy for both parties if:

$$\alpha(e_2)P < B < [1 - \alpha(e_2)]\bar{l}. \tag{16}$$

If these inequalities hold, there is corruption. Anticipating this, at the production stage the firm chooses $q = 0$, so that the legal standard is ineffective. Since firms are identical, none will obey the law and the market will collapse. Hence, the government must choose s and e so that the interval defined by the inequalities in (16) is empty, that is, $\alpha(e_2)P \geqslant [1-\alpha(e_2)]\bar{l}$. This constraint sets a lower bound on the amount of resources to be devoted to enforcement, to discourage corruption:

$$e_2 \geqslant \alpha^{-1}\left(\frac{\bar{l}}{P + \bar{l}}\right). \tag{17}$$

Intuitively, the government must intensify the enforcement up to the point where the fear of being caught is so great that entrepreneurs and officials will not deem it worthwhile to collude. The level of enforcement necessary to prevent corruption naturally decreases as the penalty P faced by corrupt bureaucrats increases, so P will optimally be set at the highest possible level consistent with the bureaucrats' endowment. Enforcement cost increase with the penalty $\bar{l}$, since corruption is more tempting when it shields firms from a higher penalty.

Formally, inequality (17) is an additional incentive constraint on the government's choice of s and e, and therefore must be added to the maximization program (11):

$$\begin{cases} \max\limits_{s,e,l} W = y + u(s) - c(s) - e_1 - e_2, \\ \quad \text{subject to (8), (10) and (17).} \end{cases} \tag{18}$$

The solution to this problem is characterized as follows:

Proposition 2 (Standard and Enforcement with Corruption) *When officials are corruptible, the optimal standard is lower than (or equal to) the second-best level, but total spending on enforcement is more than in the second best.*

Proof. See Appendix A.

The reason why potential corruption reduces the optimal quality standard is that it requires additional resources to monitor lower-tier officials (e_2). As the legal standard is lowered, the government will also reduce the resources for policing it, e_1 (due to the complementarity shown in Lemma 1). However, as is shown in the proof of Proposition 2, this is more than offset by the spending on internal monitoring of officials, e_2, so that total spending on enforcement $e_1 + e_2$ exceeds spending on enforcement e when bureaucrats are not corruptible.

This result parallels the insight from the model by Acemoglu and Verdier (2000), who show that potential corruption requires an increase in the resources spent on bureaucrats, in order to secure the same level of enforcement. In their setting, the increased spending arises from the need to provide the appropriate incentives to corruptible bureaucrats: as in efficiency-wages models, high wages deter officials from misbehaving. In our setting, costly monitoring by upper-tier functionaries performs the same role of deterring lower-tier bureaucrats from taking bribes. This difference is inessential, since increased reliance on any of these two incentive devices leads to increased spending on enforcement (higher wages in Acemoglu and Verdier, higher monitoring costs in our setting). A more substantive difference lies instead in the fact that we treat the design of the law as endogenous. This leads to the result that, when bureaucrats are corruptible, a benevolent government must relax the legal standard relative to the second-best level.

Proposition 2 implies that there are even situations in which a government with corruptible officials will refrain from imposing a positive legal standard, whereas with no corruption it would set such a standard (from Proposition 1). This will happen if the country is sufficiently poor, as the following example illustrates.

3.2.1 Example - Continued

Consider corruptible bureaucrats in the context of the example set forth in the previous section. The maximization problem (18) becomes:

$$\begin{cases} \max_{s,e,l} W = y + \theta s - ks^2/2 - e_1 - e_2, \\ \text{IC: } ks^2/2 \geqslant kq^2/2 - he_1 l, \ \forall q \neq s, \\ \text{NC: } e_2 \geqslant \bar{l}/a\left(P + \bar{l}\right), \\ \text{F: } x \equiv y - ks^2/2 - e_1 - e_2 \geqslant 0. \end{cases}$$

In this example inequality (17) takes the form of the constraint (NC), which stands for "No Corruption". This is the only addition to the example developed in the previous section.

We assume that the probability of detection is linear in enforcement effort:

$$\alpha(e_2) = ae_2,$$

with $a > 0$ and $e_2 \in (0, 1/a)$.

The constraint (NC) is binding, while the feasibility constraint (F) may or may not be binding. For $x > 0$ (F not binding), the solution to this maximization problem yields the following values for the legal standard, the enforcement level, the numeraire consumption and the social surplus:

$$s^{**} = s^*, \quad e_1^{**} = e^*, \quad e_2^{**} = \frac{\bar{l}}{a\left(P + \bar{l}\right)}, \quad x^{**} = x^* - e_2^{**} \quad W^{**} = W^* - e_2^{**}. \tag{19}$$

This shows that when resources are sufficiently plentiful, the optimal standard is the same as with incorruptible officials, and so is the amount of resources spent directly on enforcement. However, the total spending on enforcement is greater, because of the need to monitor officials.

For $x = 0$ (F binding), it must be that $x^{**} \equiv y - ks^2/2 - ks^2/2h\bar{l} - \bar{l}/a\left(P + \bar{l}\right) = 0$, so that the constrained second-best quality standard is:

$$s^{**}(y) = \max\left\{\sqrt{\left(\frac{2y}{k} - \frac{2\bar{l}}{ka\left(P + \bar{l}\right)}\right)\frac{h\bar{l}}{1 + h\bar{l}}}, 0\right\}. \tag{20}$$

First, comparing (20) with (15), the legal standard is strictly lower with corruption than without: $s^{**}(y) < s^*(y)$. Second, for sufficiently low values of income y, expression (20) becomes zero, implying that the government will not impose a legal standard, in contrast with what happens in the absence of corruption. The standard is positive only for $y > \bar{l}/a\left(P+\bar{l}\right) = e_2^{**}$. Third, the legal standard achieves its maximal value (the second-best level s^*), for levels of income higher than the threshold $\theta^2 h\bar{l}/[2k(1+h\bar{l})] + \bar{l}/a\left(P+\bar{l}\right)$. This threshold is higher than its no-corruption analogue, which is $\theta^2 h\bar{l}/[2k(1+h\bar{l})]$.

[Insert Figure 5]

Taken together, the expressions in equations (19) and (20) describe how legal standards vary with the wealth of nations (graphed in Figure 5). Very poor countries set no standard at all. Poor countries set a lower than without corruption, while very wealthy countries do not distort the standard because of corruption.

4 Self-Interested Government

So far, the government has been assumed to be benevolent, that is, to maximize social welfare. However, a government may also be, at least in part, captured by corrupt bureaucrats. In this case, it may attach a positive weight to the bribes that can be extracted from non-complying firms, as is assumed in the "tollbooth view" of regulation proposed by Djankov et al. (2002). In the context of our model, we can assume that the government's objective function (now denoted by $\widetilde{W}$) counts as values both social welfare W and the expected bribes $E(b)$ arising from non-compliance. The weight of the latter, γ, stands for the degree of government's self-interest:

$$\widetilde{W} = (1-\gamma)W + \gamma E(b). \tag{21}$$

This setting differs from that examined in the previous section, where bureaucrats are corruptible but the government controls them by a system of penalties. We now assume that the penalties are absent, to allow for the possibility that the government itself is captured by its officials, who are not punished for accepting bribes. For simplicity, corrupt officials are assumed to extract the highest possible bribe from non-compliers, i.e., the maximum penalty $\bar{l}$. Denoting the fraction of non-compliers by $f(s,e)$ and recalling that firms are inspected with probability $p(e)$, the expected bribes are $E(b) = f(s,e)p(e)\bar{l}$.

We cannot analyze this case without assuming some heterogeneity among firms. If all firms are identical, either all obey the law or none do. In the first case, there is no corruption in equilibrium. In the second, the market for the quality good collapses, because consumers anticipate that the quality level will be zero. But if firms are heterogeneous, a self-interested government can extract bribes from some while enforcing the standard on the others.

Suppose that firms can be of two types: low-cost firms, with cost function $c_L(s) = c(s, k_L)$; and high-cost firms, with cost function $c_H(s) = c(s, k_H)$, where $k_H > k_L$. The fraction of low-cost firms is ϕ. Neither government nor consumers know which type any given firm is, but they do know the distribution of types.

4.1 Design of the Law and Extraction of Bribes

The government chooses the standard s and the enforcement level e so as to maximize its objective function (21). But it must also decide whether to provide incentives for both types or only for low-cost firms. A self-interested government decision process has two stages. First, the government chooses between a no-bribe regime (both types of firms obey the law) and a bribe regime (only the efficient firms respect the law). Second, in each regime, the government selects the optimal standard consistent with its degree of self-interest γ and with the other parameters.[9]

If the government decides to give incentives to both types, it must make sure that the high-cost firms' incentive constraint is met. This implies that also low-cost firms have the incentive to respect the law. Since the fraction of non-compliers $f(s, e) = 0$, expected bribes $E(b)$ are zero in (21). The government's objective therefore is:

$$\widetilde{W}_{LH} = \max_{s,e} \widetilde{W} = \max_{s,e} (1 - \gamma) [x + u(s)] . \tag{22}$$

subject to the incentive constraint:

$$v(s) - c_H(s) \geqslant v(s) - c_H(q) - L(e, q, s, \bar{l}), \ \forall q \neq s \tag{23}$$

and the feasibility constraints:

$$x + [\phi c_L(s) + (1 - \phi)c_H(s)] + e \leqslant y + \phi[c_H(s) - c_L(s)], \tag{24}$$

$$x \geqslant 0. \tag{25}$$

The feasibility constraint (24) differs from the corresponding constraint with one type of firm in (9): on the left-hand side, one must consider the costs of both types of firms, while on

[9] In principle, the optimal mechanism would require the government to set two different standards for high-cost and low-cost firms, rather than a single standard as is assumed here. It is possible to show that under this assumption our results would be qualitatively unchanged. The rationale for focusing on a single-standard mechanism is twofold. For one thing, it is analytically simpler since it avoids the two revelation constraints of the problem. What is more, it is more realistic. Generally, legislation specifies a single quality standard, irrespective of producers' costs.

the right-hand side one must take into account that households' resources include the profits made by low-cost firms $\phi\left(c_H(s) - c_L(s)\right)$. These profits arise because under competition the price equals the cost of the marginal, inefficient firms.

If instead the government decides on incentives for low-cost firms only, its objective becomes:

$$\widetilde{W}_L = \max_{s,e} \widetilde{W} = \max_{s,e} (1-\gamma)\left[x + \phi u(s)\right] + \gamma(1-\phi)p(e)\bar{l}. \tag{26}$$

subject to the incentive constraint:

$$v(s) - c_L(s) \geqslant v(s) - c_L(q) - L(e, q, s, \bar{l}),\ \forall q \neq s \tag{27}$$

and the feasibility constraints:

$$x + \phi c_L(s) + e \leqslant y, \quad x \geqslant 0.$$

This objective (26) differs from (22) for two reasons. First, the expected utility of consumers is $\phi u(s)$, reflecting that the product has quality s with probability ϕ, and zero otherwise. Second, since the fraction of non-compliers is $f(s,e) = 1-\phi$, the expression includes a term for expected bribes: $E(b) = (1-\phi)p(e)\bar{l}$.

Whether the government chooses incentives for both types of firms or only for the efficient ones depends on the value of its objective function $\widetilde{W}$ in the two cases. Formally, the government's problem is $\max\left\{\widetilde{W}_{LH}, \widetilde{W}_L\right\}$.

We prove two results. First, a sufficiently self-interested government will set standards that induce the less efficient firms to violate the law. More specifically, in a situation where a benevolent government would give incentives to both types, self-interested governments may provide them only for low-cost firms and extract bribes from the others. Second, if the government extracts any bribes, the greater its degree of self-interest γ, the higher the legal standard and the enforcement level, and the more bribes it will extract. In more formal terms:

Proposition 3 (Legal Standard and Bribes) *If for $\gamma = 0$ the government provides incentives to both types of firm, for some $\gamma \in (0,1]$ it does so only for low-cost firms and extract bribes from high-cost ones. In this case, the legal standard, enforcement and amount of bribes increase in γ, if an optimal standard exists and is interior.*

Proof. See Appendix A.

An empirical implication of this proposition is that, among countries where there is corruption, bribes should be positively correlated with the legal standard and the enforcement level. The relationship between bribes and standard is the same increasing and convex function that relates the level of enforcement to the legal standard in Figure 2, since from Lemma 1 $E(b) = (1-\phi)p(e)\bar{l} = (1-\phi)c_L(s)$. Assuming that technology is similar across countries (so that both $c_L(\cdot)$ and ϕ are approximately the same), countries with high legal standards s will be characterized by comparatively high bribes $E(b)$, both observable variables being driven by unobservable cross-country variation in the degree of government opportunism γ.

Proposition 3 analyzes the behavior of a government that extracts bribes and characterizes the legal standard it chooses. However, it does not compare this legal standard with that of a government that does not extract bribes. In particular, it should not be read as implying that in a regime with bribes the legal standard will always be higher than in the no-bribe regime. In fact, we can show that:

Proposition 4 (Bribe versus No-Bribe Regime) *The standard set by a government that does not extract bribes is invariant to its degree of self-interest γ and may be either lower or higher than the standard chosen by a government that does extract bribes.*

The first result in this proposition is immediate: if expected bribes are zero, the objective function of the government reduces to (22), where γ appears as multiplying the whole function. The second result is shown below by way of an example, which also provides some intuition about the proposition.

4.1.1 Example - Continued

The example is the same as that developed in the previous sections, except that now firms are of two types. Their respective cost functions are $c_L = k_L q^2/2$ and $c_H = k_H q^2/2$. Denote $k_L = k$ and $k_H = k(1+d)$, so that d is the percentage difference between their marginal costs. We assume that half the firms are low-cost, that is $\phi = 0.5$, and we set $h\bar{l} = 1$.

If the government wants to incentivize both types, its problem is:

$$\begin{cases} \widetilde{W}_{LH} = \max\limits_{s,e} \widetilde{W} = \max\limits_{s,e} (1-\gamma)\left[y + \theta s - ks^2/2 - e\right] \\ \text{IC: } k(1+d)s^2/2 \geqslant k(1+d)q^2/2 - e,\ \forall q \neq s, \\ \text{F: } x \equiv y - ks^2/2 - e \geqslant 0. \end{cases}$$

If instead the government decides to incentivize low-cost firms only, its problem becomes:

$$\begin{cases} \widetilde{W}_{L} = \max\limits_{s,e} \widetilde{W} = \max\limits_{s,e} (1-\gamma)\left[y + \theta s/2 - ks^2/4 - e\right] + \gamma e/2 \\ \text{IC: } ks^2/2 \geqslant kq^2/2 - e,\ \forall q \neq s, \\ \text{F: } x \equiv y - ks^2/2 - e \geqslant 0. \end{cases}$$

The decision of the government is made in two steps: first, the choice of the optimal standard and enforcement in each regime; second, the choice of the best regime, based on comparison of the two maximized value functions.

The enforcement e required for quality standard s is $e(s) = [k(1+d)/2]s^2$ in the first regime, and $e(s) = (k/2)s^2$ in the second, by Lemma 1. Assuming that the feasibility constraint (F) is not binding ($x > 0$), in each of the two regimes the optimal standard is found by maximizing W with respect to s, after substituting out $e(s)$. The value functions and the optimal legal standards are respectively:

$$\begin{aligned} \widetilde{W}_{LH} &= (1-\gamma)y + (1-\gamma)\frac{\theta^2}{2\,(2+d)\,k}, \qquad s^*_{LH} = \frac{\theta}{(2+d)k}, \\ \widetilde{W}_{L} &= (1-\gamma)y + \left(\frac{1-\gamma}{3-4\gamma}\right)^2 (3-\gamma)\,\frac{\theta^2}{4k}, \qquad s^*_{L} = \frac{\theta(1-\gamma)}{k(3-4\gamma)}. \end{aligned}$$

We consider two different parameterizations:a large cost difference between the two classes of firm ($d = 1$) and a small one ($d = 0.1$). The two cases are illustrated in the two panels of Figure 6.

[Insert Figure 6]

Case (i): $d = 1$**.** As predicted by Proposition 3, the government opts for the no-bribe regime if its degree of self -interest is low enough ($\widetilde{W}_{LH} \geqslant \widetilde{W}_L$ for $\gamma \in [0, 0.347]$), and otherwise for bribes ($\widetilde{W}_{LH} < \widetilde{W}_L$ for $\gamma \in (0.347, 0.75)$, while no interior optimum exists for $\gamma \geqslant 0.75$). Consistently with the second part of Proposition 3, in the regime with bribes the legal standard s^*_L, enforcement and bribes all increase in the degree of self-interest γ. Moreover, as stated in the first part of Proposition 4, in the no-bribe regime the standard is invariant with respect to γ. Finally, in this case the legal standard in the regime with bribes is always higher than in the no-bribe regime: $s^*_L \geqslant s^*_{LH}$. Notice that, even though the standard increases from s^*_{LH} to s^*_L, the average quality in the market may decrease due to the decrease in the number of law-abiding firms.

Case (ii): $d = 0.1$**.** In this case the interval corresponding to the no-bribe regime is larger ($\widetilde{W}_{LH} \geqslant \widetilde{W}_L$ for $\gamma \in [0, 0.445]$ and $\widetilde{W}_{LH} < \widetilde{W}_L$ for $\gamma \in (0.445, 0.75)$). All the other results are as in case (i), except for the fact that with bribes the legal standard is lower than without ($s^*_L < s^*_{LH}$) for $\gamma \in (0.445, 0.474)$, but becomes higher for larger values of γ. This proves the second part of Proposition 4: the regime with bribes may have either a lower or a higher standard than the no-bribe regime.[10]

[10] It may appear puzzling that, as γ exceeds 0.445, high-cost firms stop obeying the law despite the drop in the legal standard. This is because the level of enforcement is reduced so much that these firms prefer to break the law, despite its greater laxity.

The reason why this non-monotonicity appears in case (ii) but not in case (i) is that a lower cost differential between the two types of firm raises the optimal standard in the no-bribe regime, since it reduces the possible profits of high-cost firms from breaching the law and so makes it easier for the government to incentivize them. As a result, the standard in the no-bribe regime can be higher than in the bribe regime, which is unaffected by the cost differential between firms.

5 Environmental Standards

Though stated as a model of quality standards, our framework can also be applied to environmental standards. The need to impose an environmental standard arises from a public-good problem, which on the face of it might seem completely different from the informational asymmetry that creates the need for product quality standards. However, the two problems are much more similar than they appear, to the point that our setting can be reinterpreted as a model of optimal environmental standards and their enforcement. The logical equivalence between the two models arises from producers' moral hazard, whether this involves the unobservable quality of their output or the environmental costs of their production technology. In both cases, government intervention is required to check the producers' conduct. In the model analyzed so far, consumers cannot observe producers' behavior. In a public-good model, they can observe it, but have no incentive to demand socially good behavior.

Suppose, as before, that consumers care about two goods – a continuous numeraire good, denoted by x, and a lumpy good, and demand a single unit of the lumpy good and a non-negative amount of the numeraire. The production of the lumpy good affects the quality of the environment: the more polluting the production technology, the lower the production cost. As before, $c(q)$ is increasing in q, this time reinterpreted as the "environmental friendliness" of the technology used. Therefore, $c(0)$ is the minimum production cost, corresponding to the most environmentally harmful technology. Therefore, per-unit profits are defined as:

$$\pi = v - c(q),$$

where v is the market price, to be determined by Bertrand competition.

In this reworking of the model, the consumer cares about the quality of the environment, not that of the lumpy good. Environmental quality, $\overline{q}$, is the average of the levels chosen by all firms: $\overline{q} = \int_0^1 q dz$. Accordingly, the utility function of consumers can be rewritten as:

$$U = x + \psi + u(\overline{q}; \theta), \tag{28}$$

where ψ is the consumer's reservation value of the lumpy good in units of the numeraire and $u(\overline{q}; \theta)$ is the utility generated by environmental quality, with θ a taste parameter. To the individual consumer, the pollution level chosen by the producer from which he buys the lumpy good has a negligible effect on environmental quality $\overline{q}$. Due to this externality, environmental quality is a public good.

In this setting, without government intervention Bertrand competition leads to the lowest environmental quality. The market price is bid down to the cost corresponding to the cheapest and most polluting technology, i.e. $v = c(0)$. This inefficiency can be remedied by setting a minimum environmental standard s for production technologies, so that $\overline{q} = s$.

Firms will recover the implied increase in production costs by raising the price of the lumpy good, and under perfect competition all of the increase will be passed on to consumers in the form of a price increase. As in section 3, a benevolent government maximizes the utility of consumers over consumption x, the environmental standard s, the enforcement level e and the penalty l:

$$\max_{x,s,e,l} U = x + \psi + u(s)$$

subject the incentive constraint

$$v - c(s) \geqslant v - c(q) - L(e, q, s, l), \ \forall q \neq s$$

and the feasibility constraints (9) and (10). Under these assumptions, therefore, the analysis of the second-best legal standard and enforcement is isomorphic to that set forth in the previous sections.

This implies that the results reached in the previous sections also apply to the design and enforcement of environmental standards. If these standards are chosen optimally, their strictness should be positively related to the resources devoted to their enforcement, and they should be higher in wealthier countries than in poorer ones. This is reminiscent of the provisions of the Kyoto Protocol, according to which developed countries ought to bear the entire financial burden of reducing greenhouse gas emissions, while developing countries are not bound to reduce future emissions, at least not immediately.

The results on corruption also carry over to environmental regulation. If governments are benevolent, countries where officials are corruptible should set lower environmental standards and allocate less resources to enforcement. Conversely, if governments are self-interested, environmental standards should be positively correlated with measures of bribes, as predicted by the "tollbooth theory".

In the following section we test these predictions using international data on the strictness of environmental regulation, the effectiveness of enforcement and the extent of corruption.

6 International Evidence

Our evidence refers only to environmental standards, since internationally comparable data about product quality standards are unavailable. We draw upon two sources for data on environmental regulation and its enforcement. The first covers a small set of countries but provides accurate survey-based measures of the strictness of regulation and the resources devoted to enforcement. The information of the second data set is less precise but covers more countries. We also construct a database with alternative measures of corruption and of other variables (education, religion, political and geographical variables) to be used in regression analysis. Detailed definitions and sources are given in Appendix B.

6.1 Data

A first set of environmental indicators is constructed from environmental reports presented to the United Nations Conference on Environment and Development (UNCED, 1992) and used by Dasgupta, Mody, Roy and Wheeler (1995). The data refer to 32 randomly selected countries of the 145 for which UNCED reports were presented. The UNCED secretariat recommended that reports be prepared by teams including government, business and non-governmental organizations (NGOs). According to Dasgupta et al. (1995), NGO participation ensured that the reports "reflect real environmental conditions and issues". We use the raw data from the reports to construct an indicator of regulatory strictness ("Environmental Legislation") and an indicator of enforcement activity ("Funds to Environmental Agency"). Appendix B describes the methods used.

A second set of two indicators is drawn from Porter, Sachs and Schwab (2001), as reported in World Economic Forum (2002), hereafter WEF. These measure a mixture of strictness and enforcement of environmental regulation for 70 countries. The "Environmental Governance" indicator is the principal component of responses to several survey questions, touching on regulation and enforcement. Another survey-based indicator measures "Compliance with Environmental Agreements".

6.2 Results

Figure 7 shows a positive correlation between countries' environmental standards and their enforcement, using the UNCED data. The correlation coefficient between these variables is 0.61, significantly different from zero at the 1 percent level. This result is in line with the prediction of Lemma 1.

[**Insert Figure 7**]

The strictness of regulatory standards has a positive and concave relationship with per-capita income, as predicted by the comparative statics of Proposition 1 and the example in Subsection 3.1.1 (see also Figure 3). This is apparent from Figure 8, which suggests that the relationship between Environmental Legislation and the logarithm of Income is positive and linear. The same pattern is found for the larger set of countries in Figure 9, based on the WEF data and gauging regulatory standards by the variable Environmental Governance.

[**Insert Figures 8 and 9**]

The data also help us to investigate the relationship between legal standards and corruption. Our analysis in Subsection 3.2 posit that, the optimal standard chosen by a benevolent government is lower when officials are corruptible, whereas a self-interested government could raise legal standards in order to extract more bribes (Section 4). Empirically, environmental standards appear to be negatively correlated with corruption, whether standards are measured by Environmental Legislation (UNCED data), as in Figure 10, or by Environmental Governance (WEF data), as in Figure 11. Both graphs rely on the Transparency International indicator of corruption. Therefore, the descriptive evidence is consistent with the prediction of the benevolent government model, rather than with the "tollbooth view".

[**Insert Figures 10 and 11**]

To check the robustness of the simple correlations revealed by descriptive evidence, Table 1 conducts a regression analysis, using measures of environmental standards as dependent variable, and the logarithm of Income and Corruption as explanatory variables.

[**Insert Table 1**]

In all the OLS regressions reported in columns 1, 3 and 5, the coefficient of the logarithm of Income is positive, that of Corruption is negative, and are significantly different from zero at standard confidence levels. The size and significance of the coefficient of Corruption is not affected by other regressors such as schooling. Therefore, OLS estimates confirm the evidence of the bivariate plots. However, these estimates may be affected by endogeneity problems, in keeping with the model of Section 4, where both standards and bribes are endogenous variables. Hausman tests reject the null hypothesis of OLS consistency in the regression reported in column 3.

Therefore we re-estimate the regressions using Schooling, Civil Rights, Latitude and Religion dummies as instrumental variables (IV). In all the IV regressions, the estimated coefficient of Income, though remaining positive, becomes insignificantly different from zero. The coefficient of Corruption remains negative and significantly different from zero; while in column 2 it gets much smaller in absolute value, in columns 4 and 6 it gets slightly larger. These results are robust to different measures of corruption, such as those provided by Kaufmann, Kraay and Zoido-Lobaton (1999).

These correlations are consistent with the normative model of section 3, but it must be acknowledged that they could have other causes as well. For instance, the positive correlation between environmental standards and per capita income may simply mean that environmental protection is a luxury good – the so-called "environmental Kuznets curve" discussed by Dasgupta, Laplante, Wang, and Wheeler (2002). In terms of our model, this amounts to assuming that the taste parameter θ itself is positively related to income y. And the negative correlation between environmental standards and corruption could arise from producers' lobbying for lower environmental compliance costs, insofar as they can appropriate these cost savings in the form of extra profits. In terms of our model, this would require firms to have some market power.

7 Conclusion

As is argued powerfully by Holmes and Sunstein (1999), entitling people to legal rights entails the budgetary costs of enforcement. This has implications for the optimal design of regulations. Here we bring out these implications using a model of legal standards, in which the design of the law and the resources assigned to its enforcement are determined jointly. A benevolent government must trade the benefit of a stricter legal standard off against the cost of its enforcement. As a result, legal standards and enforcement are complements, and both increase in per capita income.

We also show that if the officials entrusted with enforcement are corruptible, the legal standard chosen by a benevolent government should be lower, to blunt the incentive for collusion with producers. In contrast, if the government itself is self-interested – in the sense that it values the bribes that bureaucrats can extract – legal standards may be increasing in corruption.

Our framework can be used in equivalent fashion to analyze both quality standards for producers (if consumers cannot observe product quality) and environmental standards (if consumers do not internalize the social cost of pollution). In both cases, government intervention is required to verify the producers' actions. International evidence on environmental regulation is consistent with our normative model: standards are correlated positively with enforcement and negatively with corruption.

Appendix A. Proofs

Proof of Lemma 1. Incentive compatibility requires the expected liability to be zero for complying firms and positive for deviant firms: $L(e, q, s, l) = 0$ for $q \geqslant s$, and $L(e, q, s, l) > 0$ for $q < s$. Setting a positive $L(e, q, s, l)$ for complying firms would obviously be pointless.

A feature of the optimal policy is that the IC constraint is binding: the producer will choose a quality level equal to the standard. If not, the government could increase welfare by lowering the cost of enforcement e, for any given s.

Therefore, one can rewrite the government's optimization problem as follows:

$$\begin{cases} \max_{s,e} W = y + u(s) - c(s) - e \\ c(s) = c(q) + p(e)\bar{l}, \quad \forall q < s, \qquad \text{(IC)} \\ y - e - c(s) \geqslant 0. \qquad \text{(F)} \end{cases}$$

If the IC constraint is binding for $q = 0$, it will also hold for any higher q, since the cost function is increasing in quality: if $c(s) = c(0) + p(e)\bar{l}$ for given s and e, then the producer is deterred from deviating to a zero quality level, and therefore *a fortiori* to any quality level will between zero and the standard s. We may then rewrite the IC constraint with:

$$c(s) = c(0) + p(e)\bar{l}, \forall s$$

We now use the IC constraint to study the relationship between s and e. If we normalize $c(0) = 0$, IC simplifies to $c(s) = p(e)\bar{l}$. Using this result, we obtain the efficient enforcement function $e = p^{-1}\left(c(s)/\bar{l}\right)$. This function is increasing:

$$p'^{-1}\left(c(s)/\bar{l}\right) c'(s)/\bar{l} > 0$$

and convex:

$$p''^{-1}\left(c(s)/\bar{l}\right)\left(c'(s)/\bar{l}\right)^2 + p'^{-1}\left(c(s)/\bar{l}\right)\left(c''(s)/\bar{l}\right) > 0$$

The signs can be easily assessed recalling that $p(\cdot)$ is increasing and concave, and that $p'^{-1}(\cdot) = 1/p'(\cdot)$. ■

Proof of Proposition 1. Here we prove only that $s^* \in (0,\, q^{FB})$ (the subsequent statements of the proposition are proved graphically in the text).

Given the foregoing analysis and the result in Proposition 1, our problem requires the solution of the following program:

$$\begin{cases} \max\limits_{s \in [0, q^{FB}]} W(s) = y + u(s) - c(s) - p^{-1}\left(c(s)/\bar{l}\right) \\ \qquad \text{s.t.} \qquad y - p^{-1}\left(c(s)/\bar{l}\right) - c(s) \geqslant 0. \qquad \text{(F)} \end{cases}$$

First, we show that $s^* < q^{FB}$. The first-order conditions of the program are:

$$u'(s) = c'(s)\left[(1+\lambda)\left(1+p'^{-1}\left(c(s)/\bar{l}\right)/\bar{l}\right)\right], \tag{A1}$$

$$\lambda\left[y - p^{-1}\left(c(s)/\bar{l}\right) - c(s)\right] = 0. \tag{A2}$$

Compared to the first-best condition $u'(q^{FB}) = c'(q^{FB})$, here the right-hand side of (A1) is larger and therefore, by the concavity of $u(\cdot)$, it must be that $s^* < q^{FB}$.

Now we show that $s^* > 0$. Let us first consider the case in which the feasibility constraint is not binding ($\lambda = 0$) and suppose that $s^* = 0$ in (A1). Recall that $c(0) = 0$ and that $\lim_{e\to 0} p'(e) = \infty$, so that $\lim_{e\to 0} p'^{-1}(e) = 0$. Therefore, equation (A1) becomes $u'(0) = c'(0)$. But this is the first-best condition, which implies $s^* = q^{FB}$, contradicting $s^* < q^{FB}$.

Next, consider the case in which the feasibility constraint is binding ($\lambda > 0$), so that $y = p^{-1}\left(c(s)/\bar{l}\right) + c(s)$. Suppose again that $s^* = 0$. By the argument just developed for $\lambda = 0$, we get $y = 0$. This contradicts the assumption that the endowment is strictly positive.

The comparative static result on $\bar{l}$ is demonstrated by differentiating the first-order condition (A1) with respect to s and $\bar{l}$, and by checking that $ds/d\bar{l} > 0$. The result on y is immediate by inspecting the feasibility constraint (A2). When this constraint is not binding, the standard s is unaffected by y. Conversely, when it is binding, s is increasing in y because $p^{-1}\left(c(s)/\bar{l}\right) + c(s)$ is increasing in s. ■

Proof of Proposition 2. Denote the values of e and s that solve program (18) by e_1^{**}, e_2^{**} and s^{**}. First, we prove that $s^{**} \leqslant s^*$.

A feature of the optimal policy is that (17) is binding and Lemma 1 implies that $e_1 = p^{-1}\left(c(s)/\bar{l}\right)$. Then substituting in the objective function we get the following program:

$$\begin{cases} \max\limits_{s\in[0,q^{FB}]} W(s) = y + u(s) - c(s) - p^{-1}\left(c(s)/\bar{l}\right) - \alpha^{-1}\left(\frac{\bar{l}}{P+\bar{l}}\right) \\ \quad\text{s.t.} \quad y - p^{-1}\left(c(s)/\bar{l}\right) - \alpha^{-1}\left(\frac{\bar{l}}{P+\bar{l}}\right) - c(s) \geqslant 0. \end{cases} \tag{F}$$

The first-order conditions of the program are (A1) and a modified version of (A2):

$$\lambda\left[y - p^{-1}\left(c(s)/\bar{l}\right) - \alpha^{-1}\left(\frac{\bar{l}}{P+\bar{l}}\right) - c(s)\right] = 0. \tag{A3}$$

Let us first consider the case in which the feasibility constraint is not binding ($\lambda = 0$); in this case the optimal s is given by (A1) and $s^{**} = s^*$. Next, consider the case in which the feasibility constraint is binding ($\lambda > 0$), so that $y - \alpha^{-1}\left(\frac{\bar{l}}{P+\bar{l}}\right) = p^{-1}\left(c(s)/\bar{l}\right) + c(s)$. Compared to the second-best, the left-hand side is smaller than in (A2) and therefore, by reason of increasing cost and probability of detection, $s^{**} < s^*$.

Next, we prove that $e^* \leqslant e_1 + e_2$.

Consider the case in which $\lambda = 0$; then, as we said, $s^{**} = s^*$ and by Lemma 1 $e^* = e_1$. Therefore the result follows for any positive e_2. Next, consider the case in which $\lambda > 0$, so that the feasibility constraint is $y - c(s^*) = e^*$ in the second-best and $y - c(s^{**}) = e_1 + e_2$ in the corruption case. Compared to the second-best, the left-hand side is greater in the corruption case, because $s^{**} < s^*$; so also, therefore, is the right-hand side. ■

Proof of Proposition 3. Let us rewrite the objective functions (26) and (22), upon substituting the relevant constraints, with more compact notation:

$$\widetilde{W}_{LH} = \max_{s,e} \widetilde{W} = \max_{s,e} (1-\gamma)\Theta(e,s), \tag{A4}$$

and

$$\widetilde{W}_{L} = \max_{s,e} \widetilde{W} = \max_{s,e} (1-\gamma)\Phi(e,s) + \gamma E[B(e)]. \tag{A5}$$

where $\Theta(e,s) \equiv [y + u(s) - 2\phi c_L(s) - (1-2\phi)c_H(s) - e]$ and $\Phi(e,s) \equiv [y + \phi u(s) - \phi c_L(s) - e]$. Denote by e^* and s^* the optimal values in problem (A4), which are independent of the parameter γ. Denote by $e^{**}(\gamma)$ and $s^{**}(\gamma)$ the optimal values in problem (A5), which depend on the parameter γ.

Consider the optimal choice of a benevolent government. That is, set $\gamma = 0$ in problems (A5) and (A4). In the proposition it is assumed that this government incentivizes both types, that is, $\max\left\{\widetilde{W}_{LH}, \widetilde{W}_L\right\} \equiv \max\left\{\Theta(e^*,s^*), \Phi(e^{**}(0), s^{**}(0))\right\} = \Theta(e^*,s^*)$. We show the first part of the proposition: some self-interested governments with $\gamma \in (0,1]$ weakly prefer incentivizing low-cost firms rather than all firms. Formally, we must check that the set $\Gamma = \left\{\gamma \in (0,1] \mid \widetilde{W}_L > \widetilde{W}_{LH}\right\} \neq \varnothing$. The values of $\gamma \in \Gamma$ satisfy:

$$\gamma \geqslant \frac{\Theta(e^*,s^*) - \Phi(e^{**}(\gamma), s^{**}(\gamma))}{\Theta(e^*,s^*) - \Phi(e^{**}(\gamma), s^{**}(\gamma)) + E[B(e^{**}(\gamma))]}. \tag{A6}$$

By assumption, $\Theta(e^*,s^*) \geqslant \Phi(e^{**}(0), s^{**}(0))$. But $\Phi(e^{**}(0), s^{**}(0)) > \Phi(e^{**}(\gamma), s^{**}(\gamma))$, since $(e^{**}(0), s^{**}(0))$ maximizes the function $\Phi(\cdot,\cdot)$. Hence, $\Theta(e^*,s^*) > \Phi(e^{**}(\gamma), s^{**}(\gamma))$, implying that the numerator of (A6) is positive and, since $E[B(e^{**}(\gamma))] \geqslant 0$, the denominator is also positive. This proves the result $\gamma \in (0,1]$.

Next, we prove the second part of the proposition: s^{**}, e^{**} and $E[B(e^{**}(\gamma))]$ increase in γ. By using Lemma 1, rewrite the incentive constraint (27) as $e = p^{-1}\left(c_L(s)/\bar{l}\right)$, substitute it into expression (26) and take the first-order condition of $\widetilde{W}_L$ with respect to s:

$$\frac{\partial \widetilde{W}_L}{\partial s} = \gamma(1-\phi)c_L'(s^{**}) + (1-\alpha)\left[\phi u'(s^{**}) - c_L'(s^{**})(\phi + p'^{-1}\left(c_L(s^{**})/\bar{l}\right)/\bar{l})\right] = 0. \tag{A7}$$

Differentiating this expression with respect to s and γ, we get:

$$\frac{ds^{**}}{d\gamma} = \frac{\phi u'(s^{**}) - c_L'(s^{**})(1 + p'^{-1}\left(c_L(s^{**})/\bar{l}\right)/\bar{l})}{\partial^2 \widetilde{W}_L / \partial s^2}. \tag{A8}$$

For s^{**} to be an interior solution, the term in square brackets in (A7) must be negative, implying that the numerator of (A8) is also negative. For s^{**} to be a maximum, the denominator $\partial^2 \widetilde{W}_L / \partial s^2 < 0$. Hence, $ds^{**}/d\gamma > 0$. Then , from Lemma 1, we immediately have $de^{**}/d\gamma > 0$. Since $E[B(e^{**})]$ is increasing in e^{**}, $dE[B(e^{**})]/d\gamma > 0$. ■

Appendix B. Definitions and Sources of Variables

Environmental Legislation: indicator of regulatory strictness. It is based on the replies to the UNCED survey question: "How extensive is the legislation so far?" Respondents could choose one of three replies: (i) "comprehensive and supported by detailed rules and regulations", (ii) "sketchy; some rules and regulations" or (iii) "only a few or none at all". These replies were coded 2, 1 and 0 respectively for each of five activity sectors (agriculture, industry, energy, transport and urban sector) and four environmental dimensions (air, water, land and living resources), totalling 20 replies. The indicator sums all the replies, thus ranging from 0 to 40 (corresponding to a "2" for all 20 replies). This variable is available for 32 countries: Bangladesh, Bhutan, Brazil, Bulgaria, China, Czech Republic, Egypt, Ethiopia, Finland, Germany, Ghana, India, Ireland, Jamaica, Jordan, Kenya, Malawi, Mozambique, Netherlands, Nigeria, Pakistan, Papua New Guinea, Paraguay, Philippines, South Korea, South Africa, Switzerland, Tanzania, Thailand, Trinidad and Tobago, Tunisia, Zambia. Source: http://www.worldbank.org/nipr/data/envperf/index.htm#Description.

Funds to Environmental Agency: indicator of the resources devoted to enforcement using replies to the UNCED survey question: "What is the extent of the allocation of funds to the environmental protection agency?" to which respondents could reply: (i) "reasonably good for carrying out allotted tasks", (ii) "some but not enough for effective functioning" or (iii) "none or very little". Replies are coded and summed as above to produce the indicator. This variable is available for the same 32 countries as Environmental Legislation. Source: http://www.worldbank.org/nipr/data/envperf/index.htm#Description.

Environmental Governance: principal component of responses to several survey questions touching on air pollution regulation, chemical waste regulation, clarity and stability of regulations, flexibility of regulations, environmental regulatory innovation, leadership in environmental policy, stringency of environmental regulations, consistency of regulation enforcement, regulatory stringency, toxic waste disposal regulations, and water pollution regulations. This variable is available for 70 countries. Source: Porter, Sachs and Schwab (2001) as reported in World Economic Forum (2002).

Compliance with Environmental Agreements: indicator obtained from survey reactions to the statement: "compliance with international environmental agreements is a high priority". Survey responses range from 1 (strongly disagree) to 7. This variable is available for 56 countries. Source: Porter, Sachs and Schwab (2001) as reported in World Economic Forum (2002).

Corruption: misuse of public power for private benefits, e.g., bribing of public officials, kickbacks in public procurement or embezzlements of public funds, as of 1999. The index averages the corruption scores given by the following sources: 1) Freedom House Nations in Transit; 2) Gallup International; 3) The Economist Intelligence Unit; 4) the Institute for Management Development, Lausanne; 5) the International Crime Victim Survey; 6) the Political and Economic Risk Consultancy, Hong Kong; 7) the *Wall Street Journal*, Central European Economic Review, 8) the World Bank and University of Basel; 9) the World Economic Forum. The original index is the "corruption perception index" produced by Transparency International and is a descending score from 1 (most corrupt) to 10 (least corrupt). We rescale it so that our "corruption" variable equals 1 for the least and 10 for the most corrupt countries. In 1999 this variable is available for 92 countries. Source: www.transparency.de.

Income: GDP per capita, constant prices (1995), average of 1994-98. Available for 117 countries. Source: Penn World Table 6.0 (PWT 6.0).

Religion: measures of the religious composition of the population that identify for the year 1980 the percentage of the population that is (1) Roman Catholic, (2) Protestant, and (3) Muslim, available for 85 countries. Source: La Porta, Lopez-de-Silanes, Shleifer and Vishny (1998) using data from World Christian Encyclopedia 1982, Worldmark Encyclopedia of Nations 1995, Statistical Abstract of the World 1995, Demographic Yearbook 1995, CIA World Factbook 1996.

Schooling: average years of schooling in the total population over age 25 in 1980, as described by Barro and Lee (1996). Available for 77 countries. Source: http://www.nber.org/pub/barro.lee.

Latitude: the absolute value of the latitude of the country, scaled to take values between 0 and 1. Available for 85 countries. Source: La Porta, Lopez-de-Silanes, Shleifer and Vishny (1998) using data from CIA Factbook.

Civil Rights: index of civil liberties, average for the 1980s, Scale from 1 (most freedom) to 7 (least freedom). Available for 81 countries. Source: http://www.nber.org/pub/barro.lee.

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Table 1. Regression Results

The dependent variable is Environmental Legislation (UNCED data) in regressions 1 and 2, Environmental Governance (WEF data) in regressions 3 and 4, and Compliance with Environmental Agreements (WEF data) in regressions 5 and 6. Regressions 1, 3 and 5 are estimated with ordinary least squares. Regressions 2, 4 and 6 are estimated with instrumental variables. The instruments are Schooling, Civil Rights, Latitude and Religion dummies. The Hausman test does not reject the hypothesis that OLS estimates are consistent in regressions 1 and 5, but rejects it at the 5 percent level in regression 3. Standard errors are reported in parenthesis. *, **, *** indicate significance at 10, 5, and 1 percent level, respectively.

Regression	(1)	(2)	(3)	(4)	(5)	(6)
Estimation Method	OLS	IV	OLS	IV	OLS	IV
Constant	19.26*	-0.08	-1.44*	0.42	-0.27	-0.52
	(11.43)	(1.76)	(0.75)	(1.40)	(1.02)	(1.72)
Log per-capita GDP	2.04**	0.19	0.30***	0.14	0.17*	0.20
	(1.00)	(0.15)	(0.07)	(0.12)	(0.09)	(0.15)
Corruption	-1.82**	-0.21*	-0.21***	-0.33***	-0.27***	-0.30***
	(0.76)	(0.11)	(0.04)	(0.07)	(0.05)	(0.09)
Adjusted R^2	0.694	0.764	0.837	0.819	0.729	0.780
Number of observations	27	20	66	49	56	46

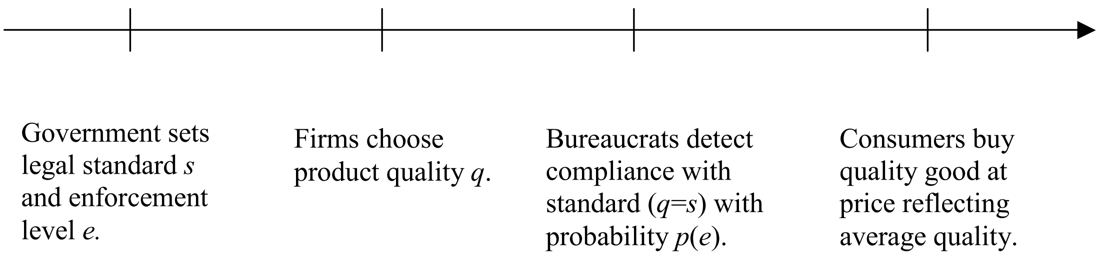


Figure 1: Time line with unobservable quality

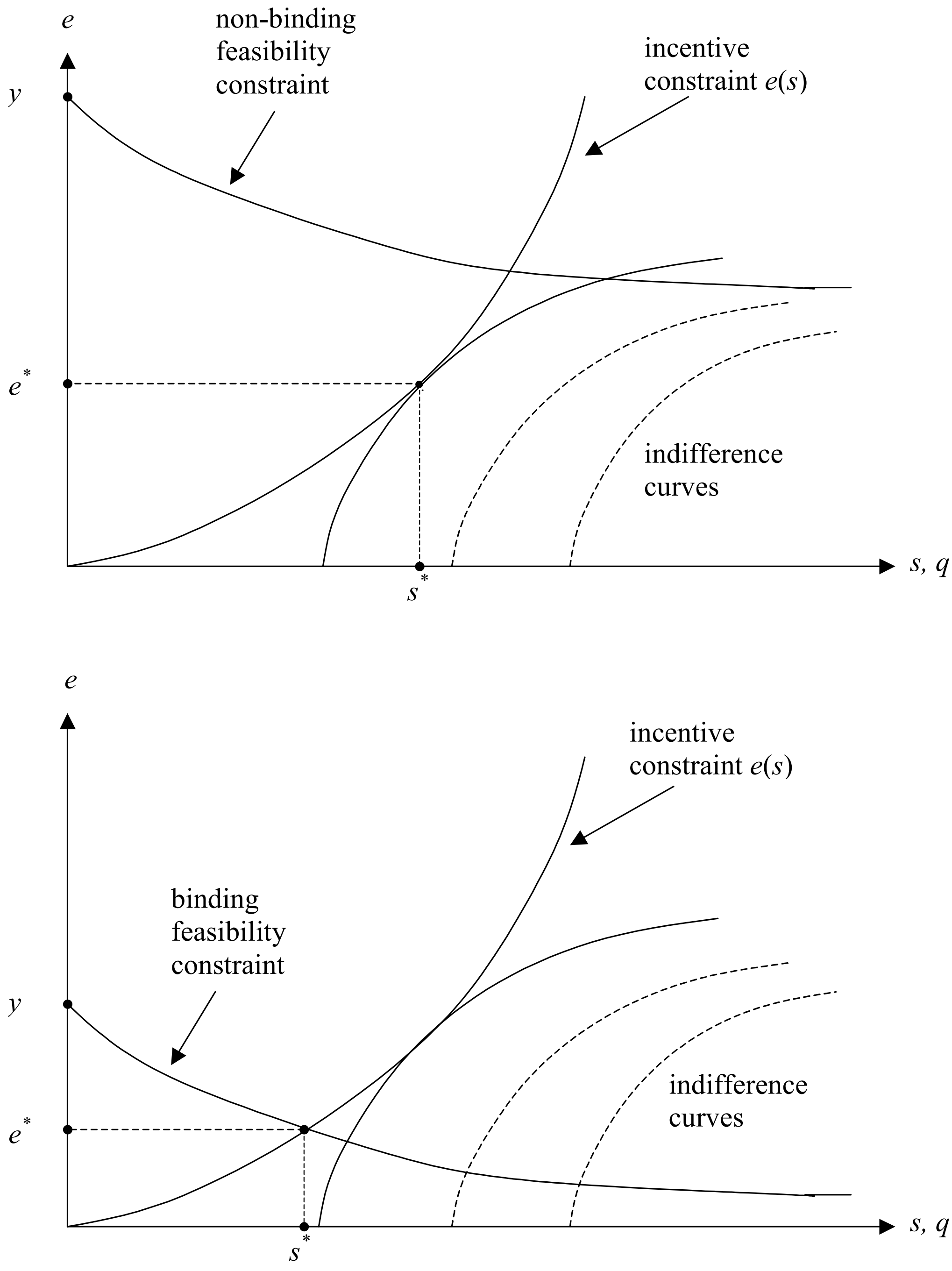


Figure 2: Equilibrium legal standards and enforcement level

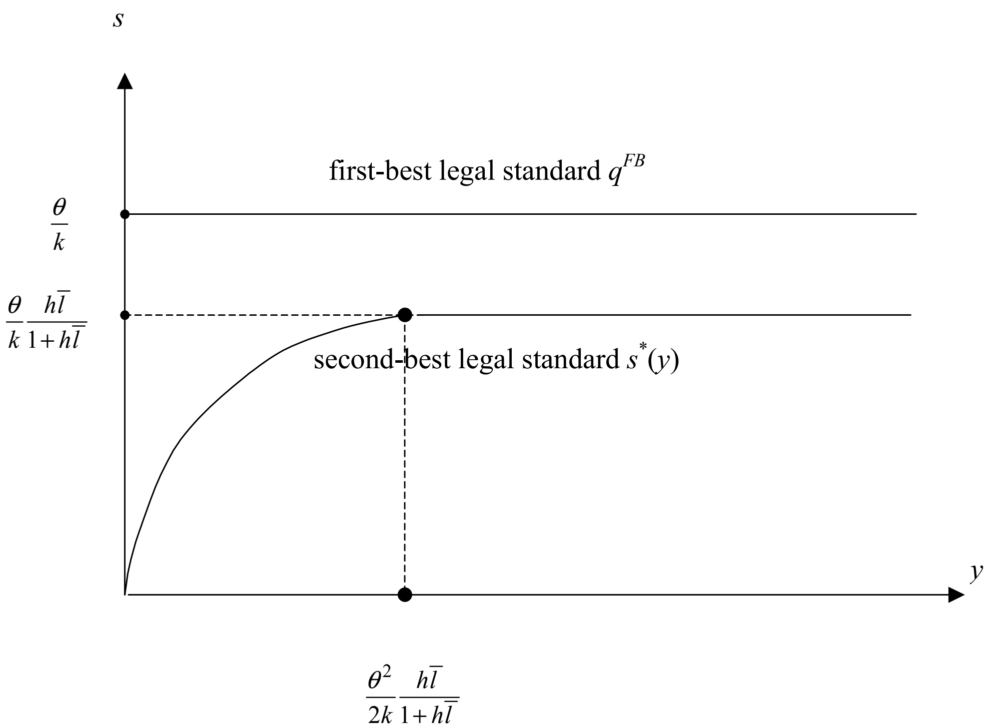


Figure 3: Equilibrium legal standards and national income

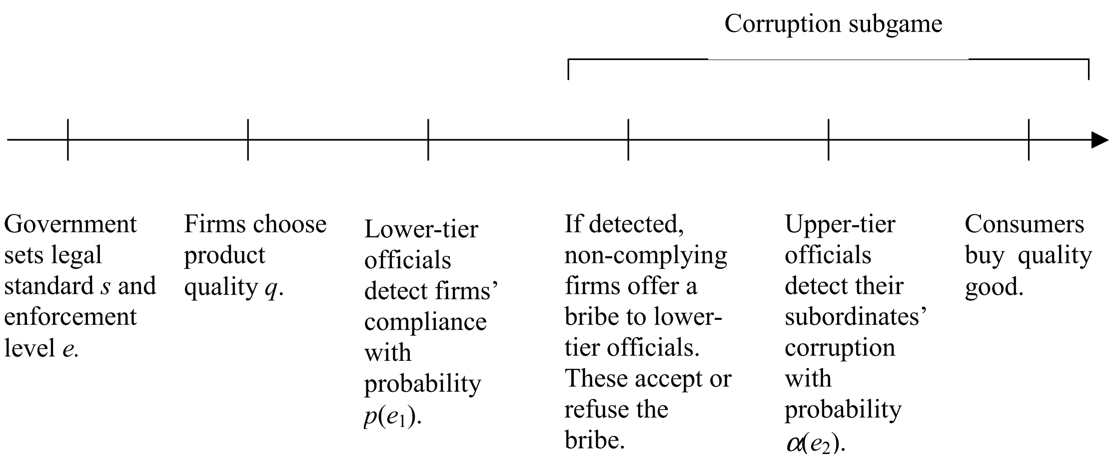


Figure 4: Time line with corruption subgame

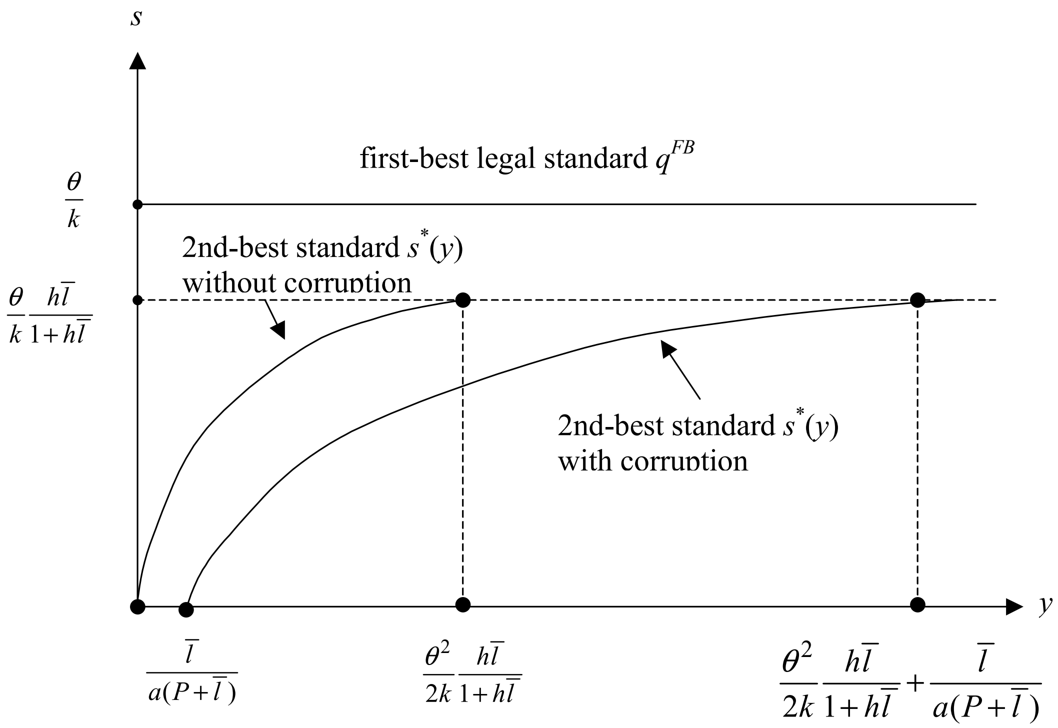
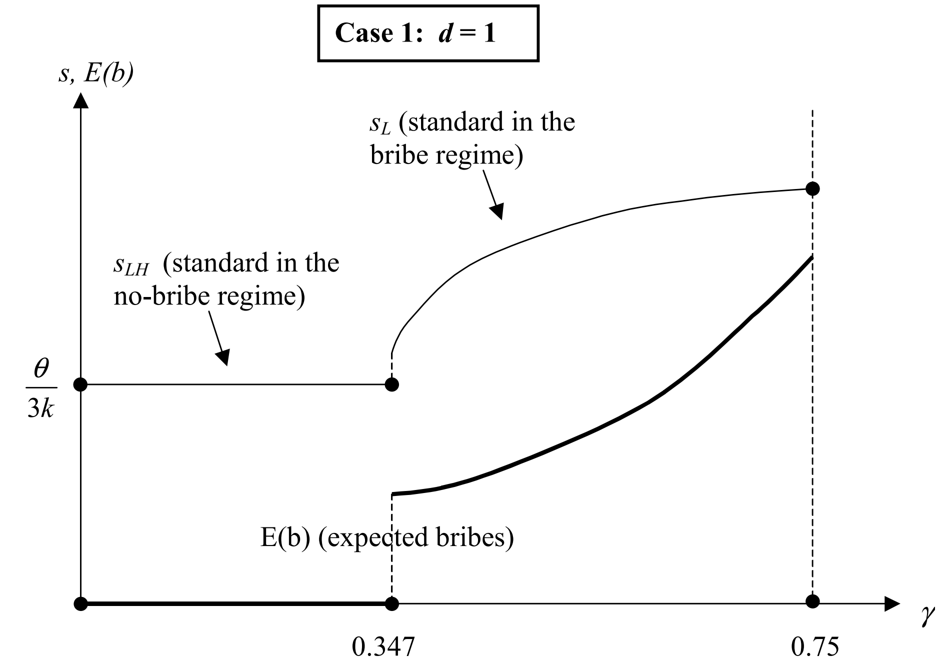


Figure 5: Equilibrium legal standard with corruption



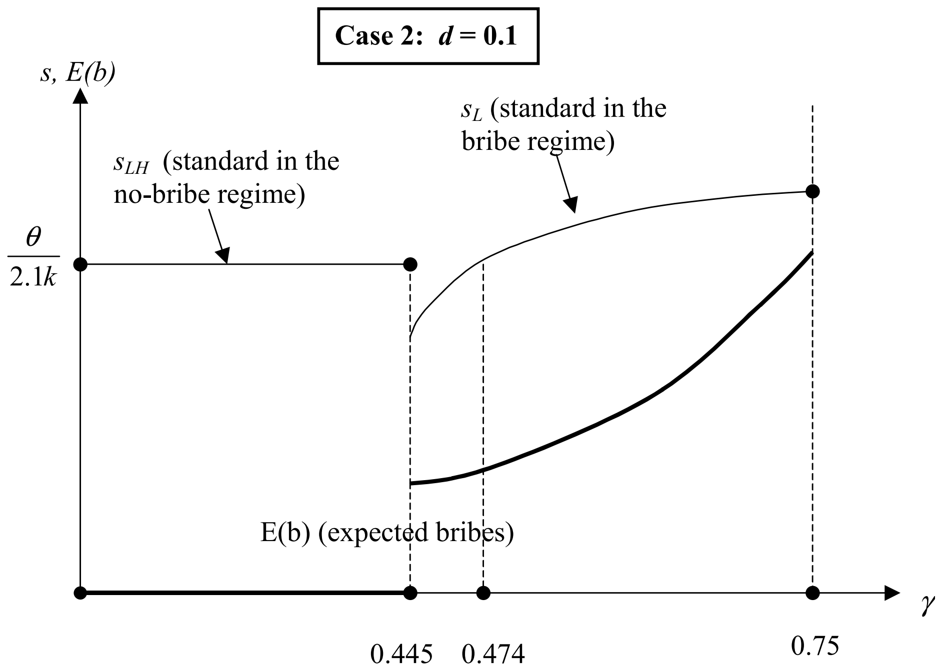


Figure 6: Legal standard and bribes with a self-interested government

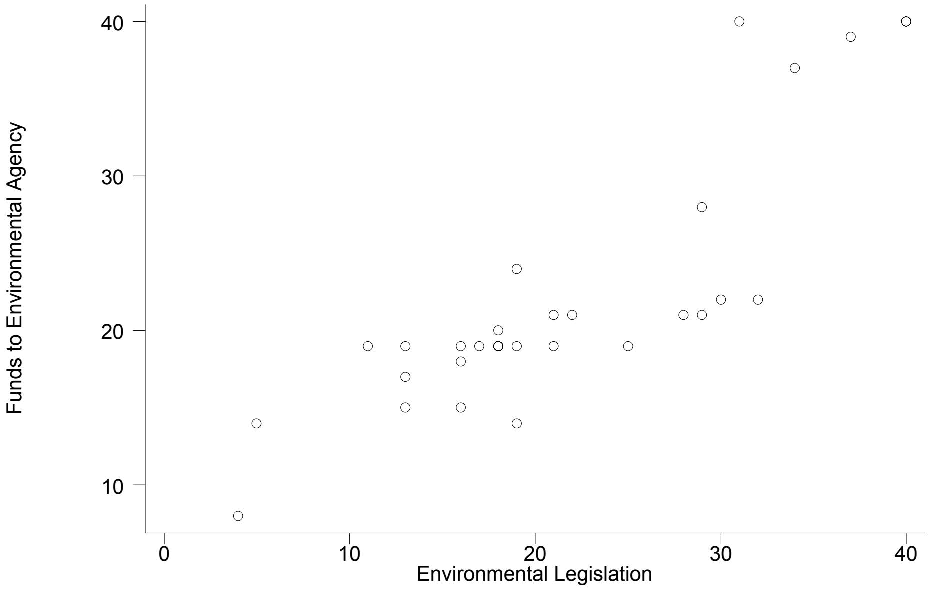


Figure 7: Environmental Standards and Enforcement (UNCED data)

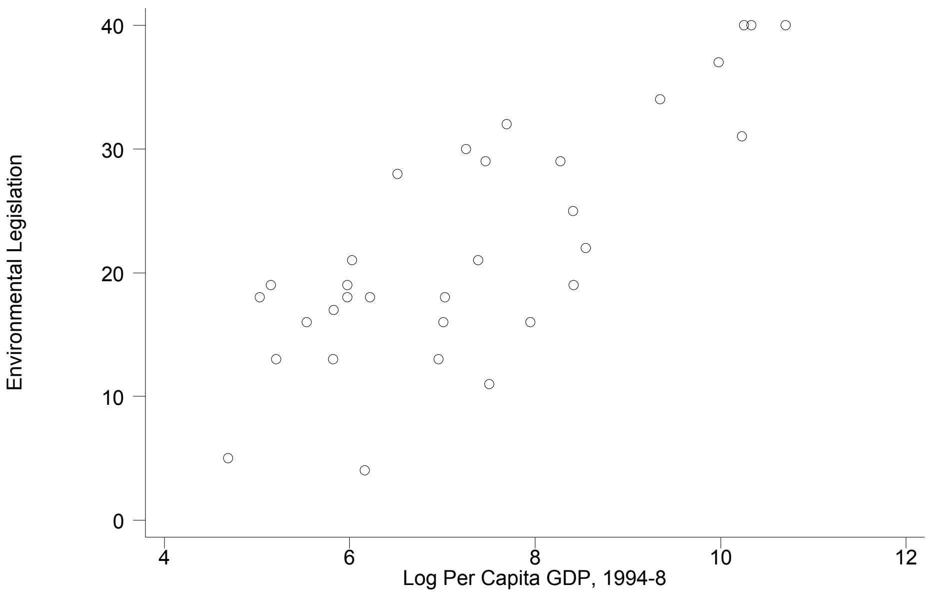


Figure 8: Environmental Legislation (UNCED data) and log per capita GDP

Figure 9: Environmental Governance (WEF data) and log per capita GDP

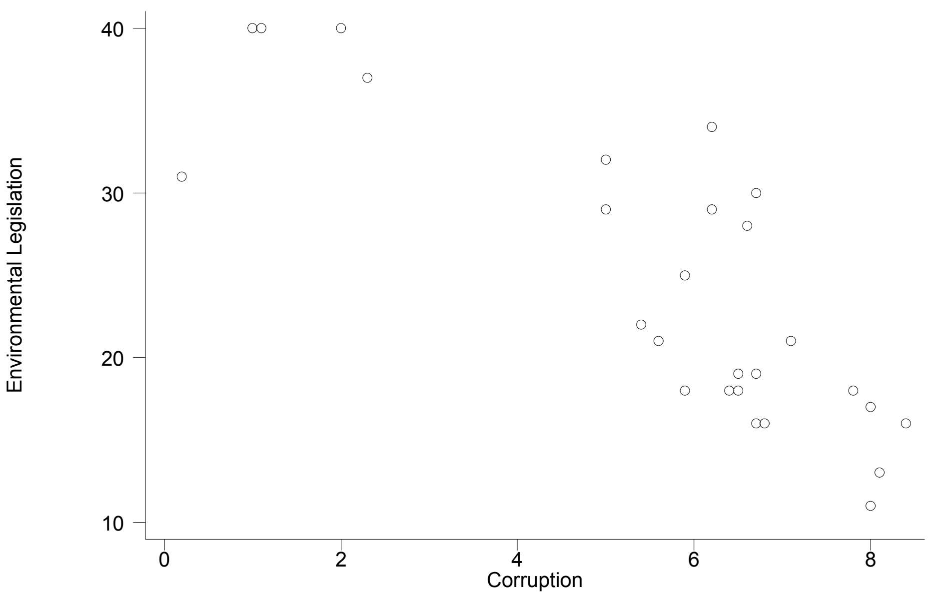


Figure 10: Environmental Legislation (UNCED Data) and Corruption

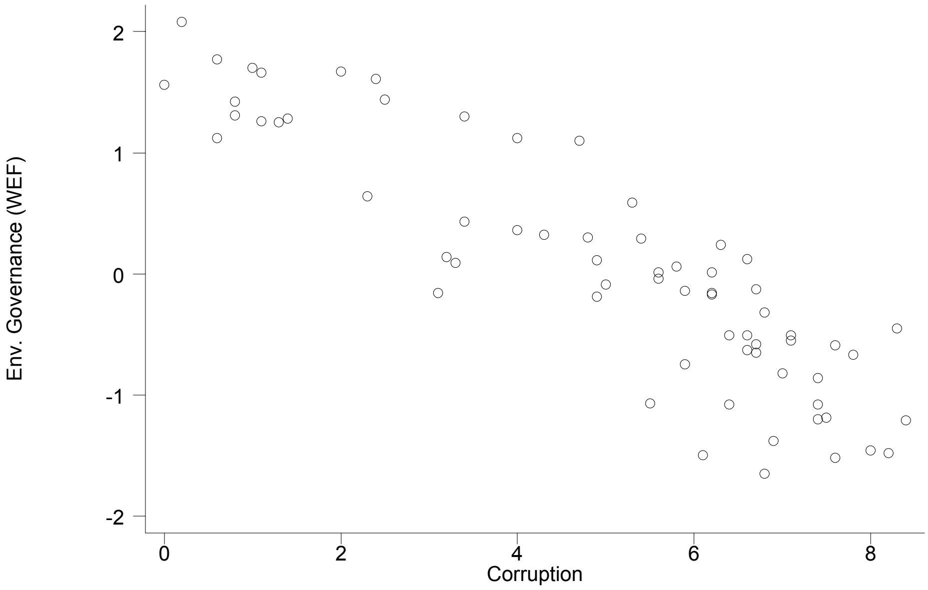


Figure 11: Environmental Governance (WEF data) and Corruption