Journal of Environmental Economics and Management **40,** 137–150 (2000)
doi:10.1006/jeem.1999.1107, available online at http://www.idealibrary.com on IDEAL®

# Corruption, Pollution, and the Kuznets Environment Curve[1]

Ramón López[2] and Siddhartha Mitra

*Department of Agricultural and Resource Economics, University of Maryland at College Park, Maryland 20742*

Received August 11, 1997; revised May 10, 1999; published online August 10, 2000

This paper examines the implications of corruption and rent-seeking behavior by the government for the relationship between pollution and growth. Cases of both cooperative and non-cooperative interaction between the government and the private firm are studied. It is shown that corruption is not likely to preclude the existence of an inverted-U-shaped-Kuznets environmental curve under both these cases. However, for any level of per capita income the pollution levels corresponding to corrupt behavior are always above the socially optimal level. Further, the turning point of the Kuznets curve takes place at income and pollution levels above those corresponding to the social optimum. © 2000 Academic Press

## INTRODUCTION

The relationship between economic growth and the environment has recently been the focus of much work. The views of environmentalists, most prominently Daly (1987), have been that economic growth, which follows observed historical patterns, causes environmental degradation. However, based on empirical evidence for a few pollutants, a school of economists believe that economic growth may cause environmental degradation at low levels of per capita income, but beyond a certain threshold, further growth is beneficial for the environment. This is the so-called Kuznets relationship. As Arrow *et al*. [1] discuss this view, policies would be responsive to people's preferences. In poor countries people value more material well-being over environmental amenities, but once a country reaches a sufficiently high per capita income, people give greater attention to the environment. This causes the political structure to respond through the implementation of environmental legislation, appropriate tax/subsidy policies, and other measures that lead to a better environment.

Recent empirical evidence showing an inverted-U-shaped relationship between certain pollutants and income has provided some support for the above-mentioned idea [8, 15]. The available empirical evidence, however, concerns only a limited number of air pollutants and some water pollutants which in general have mostly local effects and are among the cheapest to abate. There are many pollutants for which there is not yet any empirical evidence. Additionally, as Arrow *et al*. [1] indicate, reductions in certain pollutants may simply reflect changes in the composition of pollution. Lower emissions of a particular pollutant may involve increases

[1] The authors are grateful to three anonymous reviewers for extremely helpful comments.
[2] Address correspondence to Ramón López, Department of Agricultural and Resource Economics, 2200 Symons Hall, University of Maryland at College Park, MD 20742. E-mail: rlopez@arec.umd.edu.



0095-0696/00 $35.00

in other pollutants. Also, there is no empirical evidence available documenting a similar inverted U-shaped curve for natural resources. On the contrary, casual empirical evidence suggests a positive relationship between natural resource degradation and per capita income.

López [11] shows that the Kuznets relationship between per capita income and the environment depends on the effect of growth on two key parameters, namely, the elasticity of substitution in production between conventional factors of production and pollution and the Frisch coefficient of preferences reflecting how the value of goods declines with income (i.e., how the marginal utility of income declines with income). López shows that the inverted U shape may occur because the value of the Frisch coefficient is likely to rise as income increases. A U-shaped relationship can also take place if the elasticity of substitution increases with income (provided that the Frisch coefficient does not fall). The elasticity of substitution mechanism, however, is likely to be weaker and is indeed dependent on the nature of technological change, which in general has an ambiguous effect on the elasticity of substitution.

The importance of the López [11] study is that it provides a theoretical foundation for the empirically observed, inverted-U-shaped relationship between pollution and per capita income. This means that the empirical findings do have a consistent underlying structural base, and hence, they may be more than just a description of the historical experience of today's industrialized economies, which are generally on the declining side of the Kuznets curve. These may be relevant to developing countries, that are still on the positively sloping side of this curve.

The structural model for the Kuznets curve proposed by López assumes that society's changing preferences, represented by the rising Frisch index, are reflected in policy changes consistent with such changes. That is, governments promptly respond to consumers' changing preferences. Otherwise, the Kuznets curve is entirely dependent on a specific form of technical change that increases the elasticity of substitution between conventional factors of production and environmental factors. In reality, governments which place administrative restrictions on pollution may have considerations other than social welfare in mind.

The possibility of using the estimated Kuznets relationships to predict the pollution performance of developing countries depends on the assumption that governments in developing countries will be approximately as effective in controlling pollution as today's governments in developed countries.[3] The issue is important because several large developing countries (most prominently, China, India, and Indonesia) are experiencing an unprecedented period of explosive growth accompanied by enormous increases in air and water pollution that are rapidly placing them among the most important polluting sources in the world.

It is well known that government institutions in developing countries are often weaker, less effective, and generally more corrupt than those in developed coun-

[3] Selden and Song [15] and Holtz-Eakin and Selden [9] have used fixed country effects models to predict pollution. If a fixed country effects model were used, then a country would retain its intercept as it moved to higher income levels. Of course, in a levels model this is simply a fixed difference, and in a logarithms model it is just a fixed percentage difference. These fixed differences are assumed not to vary with income, but we show that these effects can indeed vary with income. However, identifying this in the data could be extremely difficult.

tries.[4] Government rent-seeking behavior, reflecting considerations other than social welfare, is much more widespread in developing than in industrialized countries. Corruption is most pervasive in many of the large, rapidly growing developing countries mentioned above. A data set of indices of countries from Business International [2] suggests that corruption is two to three times more widespread in developing than in industrialized countries. Additionally, several authors have shown that rent-seeking is an integral part of government behavior in developing countries. Krueger [10], for example, shows that in India rents amounted to more than 7% of the Gross National Product in 1964.

There is evidence to suggest that corruption and lobbying by vested interests are important sources of environmental degradation in developing countries. Desai [4] is an important source of such evidence, with case studies of 10 countries. After a thorough review of the evidence for India, R.K. Sapru, in this volume [4], reaches the following conclusion:

> The practice of large scale corruption and other forms of bribery among officials has stalled the implementation of pollution control laws to a significant extent. Industry owners commonly perceive that public servants can be bought by monetary incentives. Therefore, industrial polluters reason that they have recourse to cheaper ways than to comply with regulations that may entail significant cost (p. 172).

It is also pointed out by Sapru that most industrialists in India have links with the ruling parties in both central and state governments. Often politics intervenes and pollution from industry continues.

Evidence for Indonesia is provided by Cribb [4]. The author concludes that the administrative elite have used their positions to capture a lion's share of the profits available in a rapidly growing economy. The Indonesian administrative elite has therefore a strong personal stake in the country's economic growth. Thus, they are reluctant to pursue environmental policies which may slow down the rate of economic growth. The few environmental policies that have been implemented have been used selectively by the government to eliminate the competition of business interests which are close to it.

Riggs and Stott [4] reach similar conclusions in their detailed study of Thailand. According to these authors, factors mitigating against implementation of policies of environmental protection are extremely pronounced. The elites with power in Thailand have found it in their interest to limit the drafting of environmental legislation and to ignore that legislation that has made its way onto the statute books, with the passive or even active cooperation of the army and government bureaucracy.

An important issue is whether corruption and other institutional weaknesses will improve with economic growth. It appears that though institutions and corruption practices are by no means immutable, they tend to evolve at a much more sluggish pace than per capita income. States exhibiting high rates of economic growth seem to gradually adopt and enforce anti-corruption laws. But this process apparently

[4] Corruption certainly exists in all countries. Though bribe-taking is generally rare in developed countries, in some of them, such as the United States, legal campaign contributions may also be subversive to the performance of the government. This is not typical, however, of most other industrialized countries, where campaign contributions are subject to much greater restraints than in the United States.

requires a long maturity period at sustained high income levels. Recent empirical work by Easterly [7], focusing on the relationship between public goods and economic growth, found that a large number of public goods tend to improve very slowly during the growth process. In particular, within certain rather broad ranges of per capita income, corruption does not at all decline with economic growth. If government institutions do not evolve with per capita income, then the turning point of the Kuznets curve for developing countries may occur at considerably higher income levels than those shown by current estimates or may not even occur at all.

It is, therefore, important to go beyond recently documented purely mechanistic interpretations of the empirical relationship between pollution and income. This paper is a step in that direction. We examine the implications of corruption and rent-seeking behavior on the part of the government for the relationship between pollution and growth and determine the conditions under which the environmental Kuznets curve is likely to arise. The key point emphasized by this paper is that the actual pollution trajectories can depart from optimal ones and that an important reason for this is likely to be government rent-seeking and corruption.[5]

Environmental regulations are not, of course, driving the patterns of corruption. Corruption is likely to be extremely broad-based and the environmental regulation component is likely to be only one of the many ramifications of corruption. In this paper we focus on how corruption may effect development and enforcement of environmental regulations, but in no way should this be interpreted as implying that this is the only factor or even a major factor affecting corruption patterns.

The environmental consequences of government corruption have not yet been formally analyzed in the literature. In other contexts, however, the most common form of modeling the interactions between governments and the private sector has been to assume non-cooperative behavior. Rodrik [14], for example, assumes a Stackelberg game. If the government acts as the Stackelberg leader, then it is classified as "hard" (autonomous). Otherwise, the government is "soft" (subordinate).[6] Rodrik shows that a subordinate state systematically underprovides economically desirable interventions and systematically overprovides politically motivated and economically harmful interventions.

In reality, the interactions between the government and the private sector might not be limited to the non-cooperative types recognized by Rodrik. In this paper we consider examples of cooperative as well as non-cooperative forms of interaction between the government and the private sector to analyze the environmental consequences of government corruption. Modeling the cooperative interaction is important because evidence of cooperative and consensual interaction between government and industry with regard to environmental decision making has been found in many countries [6]. The form of cooperative interaction that we consider is a variant of a Nash bargaining model. We consider the Stackelberg model to be the form of non-cooperative interaction.

[5] Though the focus of this paper is the environment–economic growth trajectory, it is important to recognize that there are other factors, such as the nature of technologies, that significantly affect pollution. In fact, energy intensity (per unit of GDP) has been declining through time in most countries, both developed and developing, thus reducing emissions of certain pollutants relative to the environment–growth trajectory.

[6] According to Rodrik's classification, the governments in India and Africa are "soft," whereas those in Japan, Korea, and neighboring East Asian economies are "hard."

The remainder of this paper is organized as follows: Section 1 examines consensual and cooperative interaction between government and firm on the basis of a "Nash bargaining" framework. Section 2 examines the non-cooperative interaction. Section 3 concludes.

## 1. COOPERATIVE BEHAVIOR AND ENVIRONMENTAL CONTROLS

The model in this section can be considered an extension of Downs' work [5]. Downs considered that the only goal of political parties is to reap the rewards of holding office. However, since Downs ruled out (by assumption) rent-seeking behavior on the part of the government, he assumed that the sole motive behind government policy formulation is the winning of elections. If one agrees with Downs on the goal of government policy-making and allows for rent-seeking behavior, then it would be correct to assume that the government maximizes a function which depends on its probability of being re-elected as well as on rents. We assume that the government has the welfare function

$$G = (1 - a)\pi + ac; \qquad 0 \leq a \leq 1, \tag{1}$$

where $\pi$ is the probability of being re-elected, $c$ is the lobby payments or rents accruing to the government, and $a$ is a coefficient[7] associated with the degree of corruptibility of the government or a measure of the importance that it attaches to lobby payments.[8]

We assume that $\pi$ is linear and increasing in social welfare for the relevant range of social welfare. We also assume that elections reveal public preferences correctly. Therefore,

$$\pi = \pi\{\mu[F(x,t),x]\}, \tag{2}$$

where $\mu$ is the social welfare function, $F$ is the national product or net revenue function, $x$ is the amount of pollution which is a variable factor of production, and $t$ is a "growth factor," say, human or physical capital that is increasing through time. Here, $F$ is assumed to be increasing and concave in $x$ and $t$. Social welfare is increasing in $F(\cdot)$ and decreasing in $x$. Thus, apart from being a factor of production, $x$ has a direct negative effect on the social welfare function $\mu$.[9] The function $\mu(\cdot)$ is assumed to be strictly concave and separable in $F$ and $x$.

Note that it is assumed that social welfare is a function of total national revenue even though part of the revenue is paid to government officials as bribes or lobby payments. This is because government officials are a noticeable part of the economy and voting population. All that bribes do is alter the distribution of income between government officials and the rest of the population. If the marginal utility of income is assumed to be constant, then the aggregate level of

[7] Here, $a$ is a structural parameter and is likely to change very gradually with time. Therefore, we ignore the change in $a$ and assume it to be a constant.

[8] For a detailed analysis of voting models see Selden and Terrones [16].

[9] In Eq. (2) we assume that the degree of corruptibility of the government affects its probability of re-election only through its effect on welfare. If government corruption had a direct effect on this probability independent of its welfare effect, then $\pi$ would also be a direct function of $a$. To include $a$ as a factor that directly reduces $\pi$ would add algebraic complications but would not change the ensuing qualitative results (see conditions (4) and (5) and footnote 8).

welfare will be a function of aggregate income and will not depend on how income is distributed. Therefore, the aggregate level of welfare will be the same irrespective of how much of the aggregate income is paid as bribes. Even if we do not assume that marginal utility of income is constant, an increase in income will lead to an increase in welfare according to the Hicks–Kaldor compensation criterion. This is because an increase in income can always be used to make one person better off without making the others worse off.

We assume that $x$ and $c$ are determined endogenously through a process of bargaining between the government and the private firm. In this case the government and the firm try to arrive at a cooperative outcome through mutual agreement. Available to them are a set of outcomes from which they can choose and a disagreement outcome, i.e., the outcome that is obtained when the government and the firm fail to arrive at an agreement. Nash [12] imposes several properties on the solution to the bargaining problem of two bargaining parties. These are (i) invariance to equivalent utility representation, (ii) symmetry, (iii) independence of irrelevant alternatives, and (d) pareto efficiency. (For details see Osborne and Rubinstein [13].) The solution to the bargaining problem which satisfies all these properties is the Nash bargaining solution. In terms of our problem, the Nash bargaining solution can be written explicitly as

$$\operatorname*{Max}_{x,c} H = \left[ac + (1-a)\pi\{\mu[F(x,t),x]\} - (1-a)\pi^*\right]\left[F(x,t) - c - \bar{P}\right]$$

$$\text{subject to } 0 \le x^* \le x \le \bar{x}, \quad (3)$$

where $x^*$ is the socially optimal level of pollution and $\pi^*$ is the probability of being elected when $x^*$ level of pollution is generated. Here, $\bar{P}$ is the opportunity income that the capitalist makes if there is no agreement between the capitalist and the government. We have chosen the units of output so that its unit price is equal to one. For simplicity the level of $\bar{P}$ is assumed to be exogenously given.

Let $ac + (1-a)(\pi - \pi^*) \equiv A$; $F - c - \bar{P} \equiv B$. Assuming interior solutions, the first-order conditions corresponding to (3) can be expressed as

$$\partial H/\partial c = 0 \Rightarrow Ba = A \quad (4)$$

$$\partial H/\partial x = 0 \Rightarrow AF_x + B(1-a)\pi_\mu[\mu_x + \mu_F F_x] = 0, \quad (5)$$

where the subscripts denote first partial derivatives.[10] Substituting (4) in (5), we get

$$F_x = -\left[\frac{1-a}{a}\right]\pi_\mu[\mu_x + \mu_F F_x]. \quad (6)$$

The term in the second set of square brackets on the right-hand-side of Eq. (6) corresponds to the total marginal effect of pollution on welfare (i.e., it includes the direct negative effect of pollution on welfare plus the indirect positive income effect). A socially optimal level of pollution, therefore, is attained when this term is equal to zero (López, 1994). From (6) it is clear that this term is negative since $F_x > 0$ and $\pi_\mu > 0$. Thus, given concavity of $\mu(\cdot)$ in $x$ and $F$, (6) implies that the

[10] The first-order conditions (4) and (5) remain unaffected if $\pi(\cdot)$ is also a linear function of $a$. Thus, the ensuing results are not affected by allowing the level of corruption $a$ to have a direct effect on the probability of being reelected by $\pi$.

Nash bargaining solution leads to equilibrium levels of pollution above the socially optimal level. Moreover, the higher the value of $a$, the more negative is the term in square brackets. Thus, a higher degree of corruption leads to a greater deviation from the social optimum.

The first-order condition represented by Eq. (6) can be expressed in the form

$$1 + \left[\frac{1-a}{a}\right]\pi_\mu\left[\frac{\mu_x}{F_x} + \mu_F\right] = 0. \tag{7}$$

Differentiating (7) with respect to $x$ and $t$ and recalling that $\pi$ is linear in $\mu$ over the relevant range, we get

$$D\,dx + \left(\frac{1-a}{a}\right)\pi_\mu\left\{F_t\left[\mu_{FF} - \left(\frac{\mu_x}{F_x}\right)\left(\frac{F_{xt}}{F_x F_t}\right)\right]\right\} dt = 0, \tag{8}$$

where $D$ is the second partial derivative of (7) with respect to $x$, and $\mu_{FF}$ and $F_{xt}$ denote second-order partial derivatives. Here, $D$ is negative by second-order conditions of maximization. The use of (8) and some manipulation shows that

$$\frac{dx}{dt} \gtreqless 0 \qquad \text{iff} \; -\frac{\mu_x}{F_x\,\mu_F}\frac{1}{\sigma} \gtreqless \eta, \tag{9}$$

where $\sigma \equiv F_t F_x / F_{xt} F$, and $\eta \equiv -\mu_{FF} F / \mu_F$. Thus, $\sigma$ is the elasticity of substitution in production between $x$ and $t$, and $\eta$ is the coefficient of relative risk aversion (or the Frisch coefficient) which gives us the relative curvature of the social welfare function in terms of output.

Now note that condition (7) can be written as

$$\frac{\mu_x}{F_x\,\mu_F} = -1 - \frac{a}{(1-a)\pi_\mu\,\mu_F} \equiv -(1+k), \tag{10}$$

where $1 + k$ reflects the trade-off between pollution and income in the social welfare function (and, therefore, $k \equiv (a/(1-a)\pi_\mu\,\mu_F))$.

Let us first consider the special case where $a = 0$; i.e., the government is a pure social welfare maximizer. From (10), $(\mu_x/F_x\,\mu_F) = -1$. Therefore, (9) reduces to the condition

$$\frac{dx}{dt} \gtreqless 0 \qquad \text{iff} \; \frac{1}{\sigma} \gtreqless \eta, \tag{11}$$

which is exactly the condition derived by López [11] for the case of a socially optimal level of pollution. That is, in this case an inverted-U-shaped relationship between $t$ and $x$ follows given the plausible condition that $d\eta/dt > 0$ and $\sigma$ is fixed or increasing in $t$ (see López [11] for details).

Now consider the case where $a$ is a positive number lying between 0 and 1; i.e., though the probability of getting elected is still a linear function of social welfare, the government maximizes a weighted combination of social welfare and bribes.

Note that in that case $(\mu_x/F_x\,\mu_F) < -1$. Use of (10) implies that (9) reduces to the condition

$$\frac{dx}{dt} \gtreqless 0 \qquad \text{iff } \frac{1}{\sigma} \gtreqless \frac{\eta}{1+k}. \tag{12}$$

Since $k > 0$, inequality (12) implies that if a turning point exists it will occur at a higher $t$ (or higher income level) than the turning point associated with the socially optimal situation. A turning point exists if $(\eta/1+k)$ is increasing in $t$ (for constant $\sigma$). Totally differentiating $(\eta/1+k)$ with respect to $t$,

$$d\left(\frac{\eta}{1+k}\right)\Big/dt = -\frac{\mu_{FF}}{(1+k)\,\mu_F}(F_t + F_x\,\partial x/\partial t)\left[1 + \eta\left(1 - \frac{k}{1+k}\right)\right]. \tag{13}$$

The term $F_t + F_x\,\partial x/\partial t$ is the net effect of factor accumulation on income, which has to be positive regardless of the size or sign of $\partial x/\partial t$. Otherwise, no factor accumulation will occur. Hence, since $(k/1+k) < 1$, the sign of (13) is positive. Thus, assuming that at low income levels (low $t$) $(1/\sigma) > (\eta/1+k)$ (and, therefore, $dx/dt > 0$), as $t$ increases eventually the inequality is reversed, at which point pollution starts declining.

Figure 1 compares the incidence of pollution in the socially optimal case with that in the corruption cooperative equilibrium, for the case of a constant $\sigma$.[11] Curve AA depicts the pollution curve for the social optimum, while curve BB shows the corruption case. Thus, although a Kuznets curve does exist in the corruption case, the turning point occurs at a higher level of pollution $(\tilde{x} > x^*)$ and at a higher level of income $(\tilde{t} > t^*)$ than in the socially optimal situation.

[11] A constant $\sigma$ is not a realistic assumption, but given difficulties in predicting the direction of change of $\sigma$ as growth occurs, we have opted to ignore such changes. In any case, an inverted-U-shaped relationship between pollution and growth also arises if $\sigma$ is increasing in income.

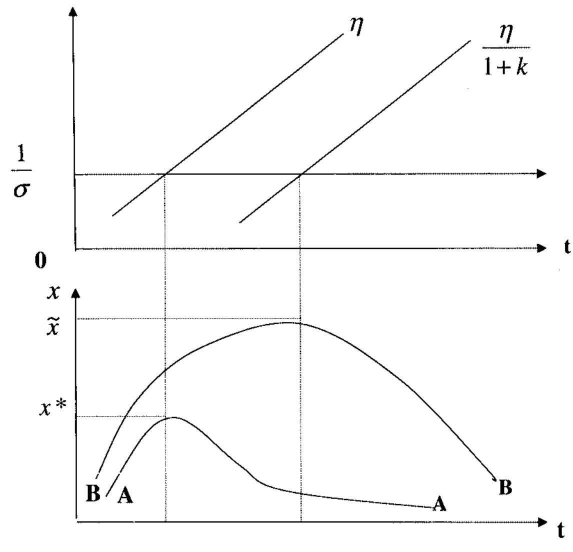


**FIG. 1.** Comparison of corruption cooperative equilibrium (BB) with social optimum AA.

The following proposition summarizes the results of this section.

PROPOSITION 1. *If corruption takes the form of cooperative government–private sector interactions, then: (i) pollution levels will be above the socially optimal levels for any level of income; (ii) an inverted-U-shaped relationship between income and pollution will exist; (iii) the turning point of the inverted U-shaped curve will occur at a higher per capita income (and higher pollution level) than in the socially optimal equilibrium.*

## 2. NON-COOPERATIVE INTERACTION BETWEEN GOVERNMENT AND FIRM

In this section we focus on non-cooperative interactions that might take place between the government and the private sector. If the government acts as a leader then the level of pollution will be equal to the social optimum. This is because the firm's reaction to any announcement of pollution by the government will be to not give any lobby payment to the government. It is easy to see that the level of pollution corresponding to Nash interaction between the firm and the government will also be equal to the socially optimal level.

We now turn to the case where the firm acts as a leader. For the purposes of our analysis we will assume that the government's maximand is given by

$$G = G\{\mu[F(x,t),x],\ \beta F(x,t)\}, \tag{14}$$

where $0 \leq \beta \leq 1$ denotes the share of its net revenues that the firm gives to government officers as a bribe. All other notation remains the same as in the previous section. Here, $G$ is assumed to be increasing and linear in $\mu$ and $\beta F$.

The interaction between the government and the private sector can be modeled as a two-stage game.[12] In the first stage the firm announces its choice of $\beta$. In the second stage the government announces its choice of $x$, i.e., the administrative upper bound on pollution.

Given linearity of $G(\cdot)$ we can write the government optimization as[13]

$$\max_x (1-a)\mu[F(x,t),x] + a\beta F(x,t). \tag{15}$$

The units of $F$ are chosen so that its price is equal to one. The first-order condition for this problem is

$$\mu_F + \frac{\mu_x}{F_x} = -\frac{a}{1-a}\beta. \tag{16}$$

[12] In this case, when the firm acts as a leader, modeling the interaction as a repeated game will not change the results because we have assumed that the firm knows the reaction function of the government exactly. Modeling the interaction as a repeated game is useful if the firm does not know the government reaction function exactly. In that case the firm gets a better idea of the reaction function of the government as the game is repeated. A dynamic game, however, could affect the results in the case where the government acts as leader. In this case the firm could renege on any promised bribe.

[13] Here we assume that the government sets quantity controls of pollution. López [11] shows that there is a price equivalence, meaning that the government can always set a tax on pollution that yields the same result. The ensuing results do not change if the government sets a pollution tax instead of a quantity control (proof available from the authors).

The left-hand-side of (16) is the slope of the social welfare in $x$ space. Maximizing social welfare implies that the left-hand-side of (16) must vanish. Given concavity of the social welfare function in $x$ (which is a required sufficient condition for a social optimum to exist), the solution of (16) implies a level of pollution above the socially optimal level. That is, the pollution−income curve in the Stackelberg equilibrium with the government as follower is always above the socially optimal pollution−income curve in the $t$–$x$ space. The solution of (16) is $\hat{x} = \hat{x}(\beta, t)$, the reaction function of the government.

The firm is assumed to know the process by which the government decides on the allowable pollution. In particular, the firm knows how changes in the bribe $\beta$ affect the allowable pollution; i.e., the firm knows the reaction function of the government. Thus, the firm's optimization consists in picking the level of $\beta$ that will maximize its share of the total revenues,

$$\max_{\beta} (1 - \beta) F(\hat{x}(\beta, t), t). \tag{17}$$

Note that since we are making abstraction of inputs other than $x$ and $t$, this is equivalent to maximizing the returns to the factors "owned" by the firm. That is, in this case maximization (17) is equivalent (e.g., yields equivalent conditions) to maximizing the share retained by the firm of the firm's revenue net of all costs other than $x$. The $F(\cdot)$ can be interpreted as a firm's net revenue function $F(p; x, t) \equiv \max_y\{py : (x, y, t) \in H\}$, where $y$ is a vector of net outputs other than $x$, with outputs having a positive sign and inputs a negative one, $p$ is a corresponding vector of net output prices, and $H$ is a feasible production possibility set. Since $p$ is exogenous, we have suppressed it from the $F(\cdot)$ function.

The first-order condition of this problem is

$$(1 - \beta) F_x \frac{\partial x(\beta, t)}{\partial \beta} - F(\cdot) = 0. \tag{18}$$

Assuming for simplicity a constant returns-to-scale Cobb−Douglas revenue function, $F = x^{\gamma} t^{1-\gamma}$, where $0 < \gamma < 1$ is a parameter, (18) can be written as[14]

$$(1 - \beta) d \ln x - \frac{1}{\gamma} d\beta = 0. \tag{19}$$

Defining $\mu_F + (\mu_x / F_x) \equiv z(x, t)$ (which corresponds to the total effect of pollution on welfare normalized by $F_x$) and differentiating (16) completely with respect to $x$, $\beta$, and $t$ yields

$$x \frac{\partial z}{\partial x} d \ln x + \frac{a}{1 - a} d\beta = -\frac{\partial z}{\partial t} dt. \tag{20}$$

[14] The use of a Cobb−Douglas specification considerably reduces the complexity of the algebra, but it does not alter the qualitative results shown in Proposition 2.

Solving (19) and (20) simultaneously yields

$$\frac{d \ln x}{dt} = \left( -\frac{\partial z}{\partial t} \Bigg/ \frac{\gamma(1-\beta)a}{1-a} + x\frac{\partial z}{\partial x} \right). \tag{21}$$

For comparison, let us consider the expression analogous to (21) for the case of a social optimum. Let the level of pollution under the social optimum be denoted $x^*$. Given that $z = 0$ at the social optimum,

$$\frac{dx^*}{dt} = \left( -\frac{\partial z}{\partial t} \Bigg/ \frac{\partial z}{\partial x} \right). \tag{22}$$

Given that $\partial z/\partial x$ is negative, by concavity of $\mu$ in $F$ and $x$, (22) and (11) can be used to yield

$$\operatorname{sign}\left( \frac{\partial z}{\partial t} \right) = \operatorname{sign}\left( \frac{1}{\sigma} - \eta \right). \tag{23}$$

Given a constant elasticity of substitution and an increasing coefficient of risk aversion, (23) implies that $\partial z/\partial t$ will be positive to start with and then turn negative as $\eta$ grows. Thus, $\partial z/\partial t$ will be a negatively sloping curve in $t$ space. A negative sign of $\partial z/\partial t$ means that the total marginal effect of pollution on welfare (i.e., considering both the direct negative effect and the indirect positive effect via income) falls as income rises.

Note that the turning point in the Stackelberg case as well as in the socially optimal case lies at the level where $\partial z/\partial t = 0$. That is, from (21) it is clear that a turning point in the pollution–income relationship also exists in the Stackelberg case.[15] However, given that pollution is higher in the Stackelberg case (from (16)) and $\partial^2 z/\partial t\, \partial x = 0$, the $\partial z/\partial t$ curve for the social optimal case lies below the $\partial z/\partial t$ curve for the Stackelberg case. This is shown in Fig. 2, where $x^*$ is the socially optimal level of pollution and $\tilde{x}$ is the level of pollution for the Stackelberg case. This implies that $\partial z/\partial t$ attains the value 0 at a higher level of $t$ in the Stackelberg case, i.e., $\tilde{t} > t^*$ in Fig. 2. Thus, the turning point for the Stackelberg case lies to the right of the turning point for the socially optimal case in $t$–$x$ space.

Thus, we have the following proposition:

PROPOSITION 2. *If government corruption takes the form of a non-cooperative Stackelberg interaction between the government and the firm, with the latter as a leader, and payment functions are linear in output, then*: (*i*) *pollution is always above the social optimum for any level of per capita income*; (*ii*) *a turning point in the pollution per capita income relationship always exists as long as a turning point exists in the socially optimal pollution–income relationship, but such a point is likely to occur at a higher per capita income* (*and higher pollution level*) *than the socially optimal one*.

Until now we have considered a payment function which is proportional to total revenues. However, there might be some non-linear payment functions which are

[15] Unlike in the case of the social optimum, in the Stackelberg case we are not sure whether this turning point corresponds to a maximum or a minimum pollution level. If the denominator in (21) were positive we would have a U-shaped, rather than an inverted-U-shaped, relationship. We, however, ignore the U-shaped case because it is rather implausible.

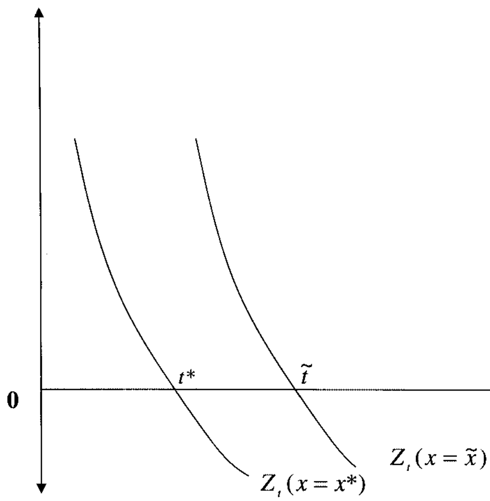


**FIG. 2.** Comparison of corruption Stackelberg equilibrium with social optimum.

realistic. For example, the firm might say that it will deposit $D$ dollars in a bank account only if $x$ is set greater than or equal to $x^*$.[16]

In Fig. 3 the inverted-U-shaped curve shows the socially optimal level of pollution at each level of income. Let us assume that the economy is initially at the level of income given by $y_0$ and the firm wants the level of pollution to be set at $x^*$

[16] We thank one of the reviewers for drawing our attention to this case.

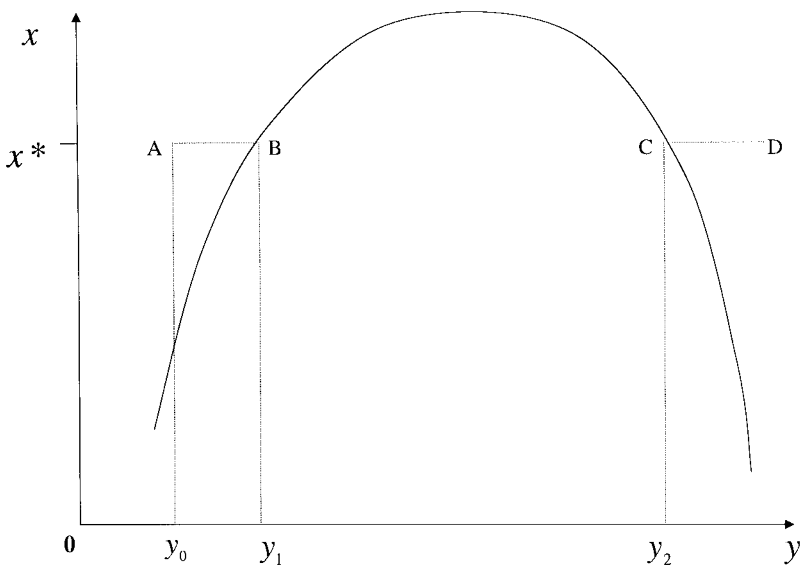


**FIG. 3.** Comparison of pollution level corresponding to a non-linear payment function (see text) with social optimum.

or above. As the level of income progresses from $y_0$ to $y_1$ the socially optimal level of pollution is less than $x^*$. Therefore, the firm has to pay the government a bribe to set the level of pollution at $x^*$. From $y_1$ to $y_2$, however, the socially optimal level of pollution is greater than $x^*$. Hence within this income range, the firm does not have to pay the government a bribe.

For output levels greater than $y_2$, the socially optimal level of pollution falls below $x^*$. Therefore, the firm again has to pay the government a bribe in order to set the level of pollution at $x^*$. The path ABCD gives the actual levels of pollution in this case for different levels of income. Note that there is a turning point in this case which coincides with the turning point of the curve which gives the socially optimal level of pollution. To conclude, pollution is greater or equal to the socially optimal level and for a certain income range it is equal to the optimal level.

A more realistic case is one in which beyond a certain level of income the firm's demand for pollution increases in proportion to its scale. In this case bribes again become proportional to the firm's revenue and the results from Proposition 2 apply.

## 3. CONCLUSION

The most important contribution of this paper is the systematic analysis of the determinants of pollution in the context of non-optimal decisions. We have explicitly considered cases where pollution levels are not necessarily consistent with maximization of social welfare. In particular, we have analyzed the implications of government corruption and rent-seeking behavior for (a) the level of pollution in an economy and (b) the changes in these levels as growth occurs. Two types of interaction have been considered, a cooperative Nash bargaining interaction and a non-cooperative Stackelberg model with the firm as leader.

It is striking that despite the contrast between the assumed behavior of firms and government that these two models imply, the results derived using each model are highly consistent. This is possibly an indication of the validity and generality of these results. Whether or not firms and government cooperate has no consequence for the effect of corruption on the evolution of pollution as income grows.

Three major conclusions emerge from the paper:

(a) Irrespective of the type of interaction between the firm and the government, for any level of per capita income, pollution levels are always above the socially optimal level.

(b) A surprising result is that corruption is not likely to preclude the existence of a Kuznets environmental curve, under either cooperative (Nash) or non-cooperative (Stackelberg) assumptions.

(c) The turning point of the Kuznets curve, however, takes place at income and pollution levels above those corresponding to the social optimum.

The implications of these results are significant particularly for large developing countries that are experiencing explosive economic growth (China, Indonesia, India, etc.) and are being affected by corruption levels notoriously above those prevailing in developed countries. Unless this growth process brings about a rapid reduction of corruption (an unlikely event given that institutions and cultural norms typically show extraordinary resilience), pollution will remain much higher in these countries than the levels reached in currently developed countries when their per capita incomes were comparable. And, more importantly, pollution in the newly industrializing countries is likely to continue increasing until their per capita income reaches levels much higher than the income at which the developed countries exhibited a turning point. That is, the empirically estimated Kuznets curves are not likely to be valid for the projection of patterns of pollution for the developing countries. In particular, the turning point for the few pollutants that have been examined (which have impacts that are mostly local in nature and are generally the cheapest to abate), which has been estimated at between $5,000 to $7,000 per capita income, may be much higher for developing countries.[17]

## REFERENCES

1. K. Arrow *et al.*, Economic growth, carrying capacity and the environment, *Science* **268**(April), 520–21 (1995).
2. Business International Corporation, "Managing and Evaluating Country Risk Assessment," BIC, New York (1984).
3. H. Daly, The economic growth debate: What some economists have learned but many have not, *J. Environ. Econom. Management* (December 14), 323–336 (1987).
4. U. Desai, (Ed.), "Ecological Policy and Politics in Developing Countries: Growth, Democracy and Environment," State University of New York Press, Albany (1998).
5. A. Downs, "An Economic Theory of Democracy," Harper & Row, New York (1957).
6. T. E. Downing and R. W. Kates, The international response to the threat of chlorofluorocarbons to atmospheric ozone, *Amer. Econom. Rev.* **72**(2), 267–272 (1992).
7. W. Easterly, Life during growth, unpublished, The World Bank (Oct. 1997).
8. G. M. Grossman and A. B. Krueger, Economic growth and the environment, *Quart. J. Econom.* (May), 353–377 (1995).
9. D. Holtz-Eakin and T. M. Selden, Stoking the fires? $CO_2$ emissions and economic growth, *J. Public Econom.* **57**(1), 85–101 (1995).
10. A. Krueger, "Perspectives on Trade and Development," University of Chicago Press, Chicago (1990).
11. R. López, The environment as a factor of production: The effects of economic growth and trade liberalization, *J. Environ. Econom. Management* **27**(2), 163–185 (1994).
12. J. F. Nash, Two person cooperative games, *Econometrica* **21**, 128–140 (1953).
13. M. J. Osborne and A. Rubinstein, "Bargaining and Markets," Academic Press/Harcourt Brace Jovanovich, San Diego (1990).
14. D. Rodrik, Political economy and development policy, *European Econom. Rev.* **36**, 329–336 (1992).
15. T. M. Selden and D. Song, Environmental quality and development: Is there a Kuznet's curve for air pollution emissions?, *J. Environ. Econom. Management* **27**(2), 147–162 (1994).
16. T. M. Selden and M. E. Terrones, Environmental legislation and enforcement: A voting model under asymmetric information, *J. Environ. Econom. Management* **24**(3), 212–228 (1993).

[17] Selden and Song [15] have shown that even if the estimated turning points for some pollutants apply to developing countries, global emissions are likely to dramatically increase. Our results reinforce such conclusions. Given that the turning points for developing countries are likely to occur at higher income levels than those projected, Selden and Song's predictions should be regarded as highly conservative.