Corruption and Natural Resource Depletion

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Abstract

The effects of corruption on natural resource depletion remain largely unexamined. Two effects can be distinguished in a theoretical model that includes a corrupt official, a resource-extraction industry, and the public: a depletion-accelerating “Hotelling effect” and a depletion-decelerating “investment effect.” A cross-country econometric analysis of 1984-2001 timber harvests indicates that the former effect is relatively stronger in less corrupt developing countries, while the latter is relatively stronger in more corrupt countries. A simulation analysis for major producers predicts that reducing corruption to the U.S. level would reduce harvests, but only by relatively modest amounts (around 10 percent of 2001 harvests).

Keywords: corruption, natural resources, timber

JEL codes: D73, Q20, Q30

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Does corruption accelerate the depletion of natural resources? Surprisingly, economists have not investigated this question carefully. It remains unanswered despite recent interest in the political economy of the “resource curse” (Michael Ross, 1999; Richard M. Auty, 2001; Jonathan Isham, Michael Woolcock, Lant Pritchett and Gwen Busby, 2003; Xavier Sala-i-Martin and Arvind Subramanian, 2003) and a spotlight on corruption related to payments for natural resource extraction rights (Susan Rose-Ackerman, 2004, pp. 34-37; Paul Collier and Anke Hoeffler, 2004, pp. 3, 12-14).

The conventional wisdom appears to be that corruption accelerates resource depletion, at least when officials who control access to natural resources do not have secure hold on office. Michael Ross (2001) cites historical evidence from timber-producing states in Southeast Asia that supports this view. Theoretical support comes from a study by James A. Robinson, Ragnar Torvik, and Thierry Verdier (2003), who develop what appears to be the first resource-extraction model linked explicitly to electoral politics. Robinson et al. are not explicitly concerned with corruption—they mention the word just once in the paper, and then in reference to a measure of institutional quality in another study—but their model resembles those in the corruption literature by representing politicians as self-interested agents who seek to maximize their income. They demonstrate that electoral uncertainty causes politicians to overextract resources in the current period compared to the socially efficient level, because it causes them to discount the future more heavily. They observe that this proposition “seems uncontroversial since it is a property of many political economy models” (p. 21).
In contrast, the literature on corruption and investment implies that corruption should have the opposite impact, that it should slow the rate of extraction. Starting with Paolo Mauro (1995), a series of studies have presented empirical evidence that corruption hinders economic growth by depressing investment. If corruption depresses investment economywide, then it might be expected to have an especially strong impact on resource-extractive industries, which are highly capital-intensive. Natural resource extraction involves investments in specialized infrastructure (roads, railroads, port facilities, pipelines), structures (oil platforms, mine shafts, logging camps), and heavy equipment (earthmoving equipment and loaders in the case of mining, skidders and log trucks in the case of logging). These investments typically must be made years before production starts, and they have limited salvage value. Henning Bohn and Robert T. Deacon (2000) present evidence that the extraction of petroleum is lower in countries where investment risks are higher. They do not include corruption in their measure of investment risk, but investors certainly do view corruption as a significant source of risk. Indeed, private firms that analyze country risks for investors are a principal source of the cross-country data on corruption used in academic studies (Daniel Kaufmann, Aart Kraay, and Pablo Zoido-Lobaton, 1999b; Michael Johnston, 2001).

In this paper we demonstrate that the impact of corruption on natural resource extraction is theoretically ambiguous and depends empirically on a country’s level of corruption. We distinguish between two effects. The first is the depletion-accelerating effect identified by Robinson et al., which we relate more explicitly to corruption than they do. Corrupt officials who control access to natural resources but face a risk of being removed from office have an incentive to shift resource extraction toward the present, while they are still in office and can capture a share of the resource rent. We call this the *Hotelling effect* in view of its connection to
Hotelling’s rule, the intertemporal efficiency condition for resource extraction (Harold Hotelling, 1931; Partha M. Dasgupta and Geoffrey M. Heal, 1979).

The second effect pertains to the negative impact of corruption on investment. Companies that obtain contracts for resource extraction by bribing officials face the risk that their contracts will be cancelled if their patrons lose office. This increases the costs of resource extraction—companies require a higher expected return on their investment—which reduces the amount of the resource they can profitably extract. This effect can depress both current and future extraction. We call it, less imaginatively, the *investment effect*.

We investigate the empirical significance of these two effects by analyzing data that have not previously been used in corruption studies. The data pertain to annual timber harvests and are drawn from the U.N. Food and Agriculture Organization’s (FAO) cross-country database on production and trade of forest products, FAOSTAT-Forestry. Corruption is widely viewed as a significant impediment to improved management of forest resources, especially in developing countries. Journalists and researchers have documented how senior government officials in timber-rich developing countries have benefited themselves, their family members, and their political supporters through the preferential allocation of logging rights (see Ross [2001] for a review and synthesis of this literature). Multilateral agencies and nongovernmental organizations have recently launched initiatives to combat corruption in the global forest sector. Transparency International established a “Forest Integrity Network” in November 2001. In the same month, the governing council of the International Tropical Timber Organization, which provides a forum for governments to discuss policy issues associated with the tropical timber trade, approved a resolution establishing a new initiative to fight corruption and other forest crimes. In 2002, the Center for International Forestry Research, which is part of the international
network of agricultural and natural resources research institutes affiliated with the World Bank and the United Nations, created a forest governance division. The initial activities of that division have focused on corruption and illegal logging. Later in 2002, the World Bank announced its new forest sector strategy, which highlights the role of governance in determining the fate of developing countries’ forests and refers specifically to corruption as an impediment to improved governance (World Bank, 2002).

The FAO forestry data are available for most countries from the early 1960s to the early 2000s. We construct a panel data set for 1984-2001 by combining the FAO data with indicators on corruption and other aspects of institutional quality produced by Political Risk Services (PRS), which is the most popular source of governance indicators used in cross-country studies (Stephen Knack, 2002, p. 10). We find that an increase in corruption tends to decrease timber harvest in countries where corruption is already at a high level but to increase harvest in countries where corruption is relatively low. This finding suggests that the investment effect dominates in highly corrupt countries—corruption drives away investment that is required to harvest timber—while the Hotelling effect dominates in countries that are less corrupt—with investment less constrained, corruption induces politicians to allow higher harvests. Econometric evidence of these effects is strongest when we limit the sample to developing countries. We use our econometric results to conduct a counterfactual analysis of the impacts of a hypothetical reduction in corruption in major developing country timber producers. For most countries we predict that harvests would fall, but the reductions are modest. Corruption does not appear to be a major explanation for timber depletion in developing countries.

The paper is organized as follows. We present our theoretical analyses of the Hotelling and investment effects in Section I. We describe our data set and discuss specification and
econometric issues in Section II. We present our results of our econometric and simulation analyses in Section III. We conclude with a recap of our main findings in Section IV.

I. Theoretical Analysis

The models in this section are intended solely to clarify the impact of corruption on the extraction of natural resources. For this reason they are much simpler than, say, the model in Robinson et al. (2003), which has additional features that link the resource sector to the rest of the economy and are necessary for investigating the “resource curse.” We develop separate models of the Hotelling and investment effects to distinguish sharply between the two effects, but the models share many basic features. We review those features, and their connections to previous studies in the literature, before analyzing the two effects.

A. General Features

Our models share several features with previous models of corruption and models in the related literature on endogenous policymaking by a self-interested government. We treat the pertinent branch of the government as a single economic agent (Robert J. Barro, 1973, 1990, section VI; Gene M. Grossman and Elhanan Helpman, 1994; Alberto Ades and Rafael Di Tella, 1997; Avinash Dixit, Gene M. Grossman, and Elhanan Helpman, 1997, section III; Robert H. Bates, Avnar Greif, Macartan Humphreys, and Smita Singh, 2004). We refer to this agent as the Minister. The Minister is an incumbent who obtains utility from bribes paid by interest groups that benefit from his actions (Andrei Shleifer and Robert W. Vishny, 1993; Christopher Bliss and Rafael Di Tella, 1997).

The Minister is risk neutral and maximizes expected utility (Rose-Ackerman, 1978, Chapters 5 and 6; Ades and Di Tella, 1997). The probability that he remains in office beyond the
current period is a function of the impacts of his actions on household welfare (Barro, 1973; Dixit et al., 1997; Bates et al., 2004). He knows this probability function (Bliss and Di Tella, 1997).\(^4\) We treat households as a single principal. We ignore details of the mechanisms by which they can remove the Minister from office (election, impeachment, protest, etc.).\(^5\) The Minister’s political competitors and his fate if he loses office are “kept in the background” (Grossman and Helpman, 1994, p. 833).

The interest group in our models is an industry that requires an input controlled by the Minister—specifically, a natural resource. The industry is legally permitted to use the resource and pays taxes on its use, but it also must make payments to the Minister to obtain extraction permits. Corruption in our models is thus an example of what Shleifer and Vishny (1993) label “corruption without theft.” The industry is competitive, with free entry (Bliss and Di Tella, 1997). It earns zero profits: competition among firms results in the Minister capturing any rent over and above the tax payments (Grossman and Helpman, 1994, Example 2 on p. 846; Dixit et al., 1997, p. 766). We ignore the possibility that the industry could organize into a single lobby and bargain with the government over the rent.\(^6\)

Like Barro (1990, section VI) and Isaac Ehrlich and Francis T. Lui (1999), we assume that the Minister has the same discount rate as households and industry. Some previous studies of self-interested government behavior assume that an imperfect grasp on power causes a government’s discount rate to exceed society’s (Bates et al., 2004). We instead treat the discount rate and the probability of remaining in office as separate factors, with the former exogenously determined and the latter affected by the Minister’s actions.
B. Hotelling Effect

Most models of corruption and self-interested government behavior are static (e.g., Rose-Ackerman, 1978, most chapters; Shleifer and Vishny, 1993; Grossman and Helpman, 1994; Bliss and Di Tella, 1997; Dixit et al., 1997; Ades and Di Tella, 1999). Yet, resource depletion is an inherently dynamic process. The model in this section has two periods, which is the minimally sufficient number for illustrating the Hotelling effect. Extending the model to an infinite number of periods, as in Robinson et al. (2003), would not change our main result, which mirrors theirs.

The resource is nonrenewable, with an initial stock of $S$. The quantity extracted in the first period is $Q_1$. Assuming an interior solution, the quantity extracted in the second period is thus $S - Q_1$. Resource rent—total revenue minus total factor costs—is an increasing function of the quantity extracted in a given period, $v[X]$, where $X$ is $Q_1$ or $S - Q_1$, depending on the period. (Throughout, we use lower-case letters to denote functions, and brackets and upper-case letters to indicate variables.) Marginal rent is positive ($v' > 0$) but diminishes with the quantity extracted ($v'' < 0$). The resource-extraction industry has only variable costs in the model in this section. Fixed costs pertain to the investment effect, which we analyze in the next section.

We seek to determine whether corruption causes $Q_1$ to be higher or lower than the socially optimal level, which maximizes the present value of resource rent,

$$W = v_1 + v_2 e^{-r}.$$  

$v_1$ denotes rent in the first period (i.e., $v[Q_1]$), $v_2$ denotes rent in the second period ($v[S - Q_1]$), and $r$ is the social discount rate. The first-order condition for $Q_1$ is

$$v'_2 = v'e^r.$$
This is Hotelling’s rule: marginal rent rises at the rate of discount along the socially optimal extraction path.

The corrupt Minister demands bribes in exchange for extraction permits. Bribes are paid at the time of resource extraction, and so the Minister receives them in the second period only if he remains in office. The expected present value of bribes is

\[ B = (1 - H)(r_1 + p r_2 e^{-r}). \]

\( H \) is the tax rate, which lies between 0 and 1. The term \( 1 - H \) indicates that bribes account for the balance of the rent that is not taxed. The Minister selects \( H \) in addition to \( Q_1 \). \( p \) is the probability the Minister remains in office \( (0 \leq p \leq 1) \). It is a function of the present value of tax revenue,

\[ p[H(r_1 + r_2 e^{-r})], \]

where \( p' > 0 \). Tax revenue is used to costlessly supply public services to households, and so it equals the contribution of resource extraction to household welfare. Note that households are not myopic: in deciding their level of support for the Minister, they consider the public services they will receive in the second period if the Minister remains in office, as well as the services they actually receive in the first period. With \( H \) the same in the two periods and \( Q_2 = S - Q_1 \), they know the amount in the second period. \( p = 1 \) if and only if the present value of public services is at the maximum, which occurs when the resource is depleted at the optimal rate \( (Q_1 = Q^*) \) and all the rent is used to finance public services \( (H = 1) \).

The Minister selects \( H \) and \( Q_1 \) to maximize \( B \). His first-order condition for \( H \) is

\[ H = 1 - \frac{r_1 + p r_2 e^{-r}}{p' r_2 e^{-r}(r_1 + r_2 e^{-r})}. \]
$H$ is nonnegative by assumption (the present value of bribes cannot exceed the present value of resource rent),\(^9\) and it is less than 1 by inspection of Equation (5). The first-order condition for $Q_1$ is
\[
\nu_1' = \nu_1^* e^{-r} - \nu_1^* e^{-r} + \nu_1^* e^{-r} + \nu_1^* e^{-r}.
\]

With $H < 1$, $p < 1$ too, and so the fraction on the right-hand side of Equation (6) is larger than 1: marginal rent rises faster than the discount rate. Under the assumption of diminishing marginal rent ($\nu'' < 0$), this is possible if and only if the amount of the resource extracted in the first period is greater than the socially optimal amount. Hence, corruption causes the resource to be depleted more rapidly than along the optimal path, i.e. to be overextracted in the first period.

Figure 1 illustrates the Hotelling effect. We have followed John M. Hartwick and Nancy D. Olewiler (1998, pp. 269-274) in defining the rent function as
\[
\nu[X] = PX - c[X],
\]
where $P$ is the price of the extracted resource, $c[X]$ is the extraction cost function, and extraction has decreasing returns to scale ($c' > 0, c'' > 0$). Hence, marginal rent is given by $\nu' = P - c'$. $Q_1^*$ and $Q_2^*$ denote the socially optimal extraction levels, which satisfy the stock constraint $Q_1^* + Q_2^* = S$ and Hotelling’s rule, $P - c^1[Q_1^*] = (P - c^1[Q_2^*]) e'$. The Hotelling effect causes marginal rent to rise more rapidly than the social discount rate, which is geometrically possible only if $Q_1^{H*} > Q_1^*$ and $Q_2^{H*} < Q_2^*$, where $Q_1^{H*}$ and $Q_2^{H*}$ are the new extraction levels and the stock constraint is still satisfied, $Q_1^{H*} + Q_2^{H*} = S$.

It is interesting to consider what happens if the Minister’s hold on office is unaffected by his actions ($p' = 0$) and is completely secure ($p = 1$), instead of depending on household welfare. In this case, Equation (6) simplifies to Equation (2), the optimal depletion condition.
Hotelling effect thus depends on corruption being combined with political insecurity; corruption alone does not lead to overextraction. The reason why a completely corrupt yet completely secure Minister selects the optimal path is easy to see from Equation (3): if \( p = 1 \), then choosing \( Q_1 \) to maximize \( B \) is identical to choosing it to maximize \( W \). This mirrors Barro’s (1990, p. S120) finding that a self-interested government with “no electoral constraints” allocates capital efficiently over time. It is also consistent with Ross’s (2001, p. 194) conclusion that timber was not extracted at an excessive rate in the Philippines and Indonesia when Presidents Marcos and Suharto, respectively, were firmly in power.

At the opposite extreme, if the Minister’s hold on office is completely insecure regardless of his actions (\( p = 0 \)), then he extracts the economically maximum amount of the resource in the first period: the amount such that \( v_1^* = 0 \). (This can be seen by setting \( p = 0 \) in Equation (3)). This parallels a finding from an earlier study by Barro (1973, p. 28), that a lame-duck, self-interested government tends to adopt policies that result in overproduction, and an observation by Rose-Ackerman (1978, p. 22) that “The political incentives for corruption … will be maximized if incumbents believe that they are certain to lose the next election.”

C. Investment Effect

To isolate the investment effect, we assume in this section that the resource is extracted in a single period. The model remains a two-period model, however, because extraction requires investment during the first period and thus does not occur until the second period. In this respect our model is similar to one by Ades and Di Tella (1997). The industry obtains extraction permits in the first period, but the permits remain valid only if the Minister remains in office. This political uncertainty puts the industry’s investment at risk (Rose-Ackerman, 2004, p. 12). The Malaysian state of Sarawak provides a dramatic example of this risk (Ross, 2001, pp. 148-9).
Following a bitterly fought election in 1986, the new chief minister canceled some 30 timber concession contracts belonging to supporters of his rival. Those concessions covered a total area of more than 1 million hectares and were valued at US$3.6-9 billion.

Permits grant the right to extract resources from specific areas. The resource stock $S$ is evenly distributed over a total area $F$, so that the amount available in any unit area is $D = S/F$. The total amount extracted is determined by the total area of permits, $A$:

$$Q = DA.$$  

Extraction requires an investment of $K$ per unit area. The optimal extraction level, $Q^*$, maximizes

$$W = v - KAe^r,$$

where $A = Q/D$ and $v$ is again resource rent, now interpreted as gross of fixed costs.\(^{10}\) The first-order condition is

$$v' = \frac{K}{D} e^r.$$  

Permits should be allocated until the gross rent on the marginal unit of the extracted resource equals the capitalized value of the unit fixed cost.

Bribes are set in the first period, when permits are allocated, and are paid in the second period, when extraction occurs.\(^{11}\) The industry does not face a risk that the Minister will unilaterally cancel the permits if he remains in office, as both parties are assumed to honor the permits (as in a study by Francis T. Lui, 1985). If the Minister loses office, however, then the industry loses its permits and earns no return on its investment. In contrast to the previous section, where only the Minister and households received any of the rent (in the form of bribes and public services, respectively), the industry now must retain some of the rent to cover its fixed...
costs and to compensate for this risk. The industry is risk neutral (Ades and Di Tella, 1997), and its expected profit is

(11) \[ pIv - KAe' \],

where \( I \) is its share of gross rent \((0 < I < 1)\). Under competition with free entry, this share is simply the amount that causes its expected profit to equal zero,

(12) \[ I = \frac{KAe'}{pv} \].

The Minister’s security in office, summarized by \( p \), thus affects the industry’s rent share.

\( p \) is again an increasing function of public services financed by resource taxes, which are assessed on the industry’s profits. The value of the services is now \( H(v - KAe') \). Households receive the services in the second period, when extraction occurs. They know this value in the first period—the government announces the amount of permits allocated and the tax rate—which as before is when they decide whether to keep the Minister in office.

The expected value of bribes collected by the Minister is given by

(13) \[ B = p(v - H(v - KAe') - Iv) \].

Political insecurity reduces his expected bribes in two ways, directly through \( p \) and indirectly through \( I \). The first-order condition for \( H \) is

(14) \[ H = 1 - \frac{p/p' - KAe'}{v - KAe'} \].

As before, we assume that \( H \) is nonnegative.\(^{12} \) For extraction to occur at all, the denominator on the right-hand side of Equation (14) must be positive. The fraction is positive, and thus \( H < 1 \), if and only if \( p' < \frac{p}{KAe'} \). For the Minister to capture some of the rent, households must not be too responsive to changes in the amount of public services they receive.
The first-order condition for $Q$ is

\begin{equation}
\nu' = \frac{K}{D} e' \frac{1}{p} .
\end{equation}

As in the case of the first-order condition for $Q_1$ in the Hotelling effect model (Equation (6)), this expression differs from the socially optimal extraction condition only by including $p$ instead of 1 in the denominator on the right-hand side. If $p'$ is below the threshold noted in the previous paragraph, then $H < 1$, $\nu' \nu$ is larger than in Equation (10), and the Minister selects an extraction level below the social optimum. Hence, corruption in the presence of fixed costs and political insecurity reduces the quantity extracted.

Figure 2 illustrates this result under the assumption that $\nu[X] = PX - c[X]$, as in Figure 1. The optimal extraction quantity is $Q^*$. The introduction of corruption, and the risk of permit cancellation that it entails, shifts the unit fixed cost of resource extraction upward from $\frac{K}{D} e'$ to $\frac{K}{D} e' \frac{1}{p}$. Hence, extraction is lower ($Q' < Q^*$).

In the case of the Hotelling effect, we found that the Minister extracts the optimal quantity if he is completely secure in office. The same is true for the investment effect: if $p = 1$, then Equation (15) simplifies to Equation (10), and the marginal cost curves in Figure 2 coincide. Like the Hotelling effect, the investment effect depends on corruption being combined with political insecurity. In the opposite case where the Minister is sure to lose office ($p = 0$), the right-hand side of Equation (15) goes to infinity, which signals that the quantity extracted falls to zero: the industry invests nothing and thus extracts nothing. This extreme case suggests that unlike the Hotelling effect, which tilts the extraction path toward the present but does not change the cumulative amount extracted over time compared to the optimal path, in a multi-period
model the investment effect could result in a smaller cumulative amount being extracted (e.g., $Q^1_t + Q^2_t < S$).

II. Empirical Analysis

Our theoretical models have two broad implications for an empirical analysis of the impact of corruption on natural resource extraction. The first is that the sign of the impact is ambiguous, with the Hotelling effect having a positive impact (corruption increases extraction) and the investment effect having a negative impact (corruption decreases extraction). These opposing effects suggest that a supply function for natural resources should include corruption in a nonlinear fashion. We used a quadratic specification in our empirical analysis. The second implication is that the supply function should also include two other groups of variables: characteristics of the resource, specifically stock ($S$), area ($F$), and stock per unit area ($D$); and economic variables, specifically ones included in the gross rent function ($v$), the discount rate ($r$), and fixed costs per unit area ($K$).

In this section we begin by describing the general specification of the timber supply function that we estimated. We then describe the construction of the variables in this function and our data sources. We close the section by discussing miscellaneous estimation issues.

One general comment is in order before turning to these matters. Our theoretical models pertain to a nonrenewable resource, but our empirical analysis concerns a renewable resource, timber. Is there an inconsistency here? Not really. Our sample period is 1984-2001. Much of the world’s timber harvest during this period came from the “mining” of timber in unmanaged forests, not plantations. This was especially true for developing countries. The global forest sector is undergoing a transition from timber mining to forest management, but this transition is
decades from completion (Roger A. Sedjo and Kenneth S. Lyon, 1990; Jeffrey R. Vincent and Clark S. Binkley, 1992; David G. Victor and Jesse H. Ausubel, 2000). Moreover, the length of time required for a seedling to grow to a mature timber tree, which is typically on the order of 30-70 years depending on the species, is much longer than our sample period. We are analyzing short-run timber supply: the timber harvested during the sample period comes from trees already in existence at the start of the period. The impact of corruption on the depletion of existing resource stocks is thus the focus of our empirical analysis, just as it was the focus of our theoretical models. Although corruption might affect investments in forest regeneration, that is a long-run effect that is different from the central concern of this paper.

A. Specification of the Timber Supply Model

Our empirical timber supply model had the following general form:

(16) \[ \text{HARVEST} = f(\text{FOREST}, \text{DENSITY}, \text{LOG PRICE}, \text{OIL PRICE}, \text{INTEREST RATE}, \text{CORRUPTION}, \text{CORRUPTION SQUARED}). \]

All variables refer to annual data for individual countries. HARVEST is the quantity of timber harvested (Q). FOREST is forest area (F), while DENSITY is volume of timber per unit area (D). We excluded the total stock of timber (S), which is just the product of F and D and contains no information independent of them. LOG PRICE and OIL PRICE are the prices of harvested logs and a barrel of oil, a proxy for the cost of energy. These are important determinants of gross resource rent (v). INTEREST RATE is the real interest rate, a proxy for the discount rate (r). CORRUPTION is an indicator of corruption in government. Although Equation (16) is based on our theoretical models, its specification accords with timber supply specifications commonly used by forest economists (see, e.g., Clark S. Binkley, 1987, pp. 116-120)—with the exception of the inclusion of the corruption variables.
The only variable from our theoretical models that is not represented directly or by proxies in the empirical model is the fixed cost of logging per unit area \((K)\), for which we were unable to obtain data. To reduce the risk of omitted variables bias, and to incorporate the effects of other country-specific factors not captured by the variables in the model, we included country fixed effects when we estimated Equation (16). To the extent that the omission of \(K\) biases our coefficient estimates, we expect it to bias mainly the coefficients on INTEREST RATE (because interest rates reflect the cost of capital) and FOREST (because fixed costs might be scale-dependent). We do not expect the bias to affect the coefficients on CORRUPTION and CORRUPTION SQUARED, which are the coefficients we are interested in.

We expressed all variables in logarithmic form except INTEREST RATE, which can be negative, and CORRUPTION (and CORRUPTION SQUARED), which as discussed in a moment can have a value of zero.

B. The CORRUPTION Variable

Cross-country data on corruption in the forest sector do not exist, although surveys of corruption in the sector are starting to be conducted in a few countries (e.g., in Indonesia; see J. Smith, K. Obidzinski, Subarudi, and I. Suramenggala, 2003). We instead based CORRUPTION on economywide indicators of corruption. We assumed that the level of corruption within the forest sector is correlated with the overall level of corruption in a country. This is a reasonable assumption, although to the extent it is violated we have an errors-in-variables problem that biases the coefficient estimates on CORRUPTION and its squared value toward zero.

One advantage of using an economywide corruption indicator instead of one specific to the forest sector is that it is unlikely to be endogenous in the timber supply function. Endogeneity of institutional variables has been a recurrent concern in cross-country studies of
investment and growth, including studies that focus on the effects of corruption (Mauro, 1995, 1997). Some cross-country studies find evidence that exports of fossil fuels, minerals, metals, and agricultural commodities are associated with lower institutional quality (Isham et al., 2003; Sala-i-Martin and Subramanian, 2003), although others do not (Ades and Di Tella, 1999; Bates et al., 2004). The forest sector is such a small component of most countries’ economies, typically less than a percentage point, that timber harvest surely has a negligible impact on economywide measures of corruption. Even in seven major timber-producing countries—Brazil, Canada, Finland, Indonesia, Malaysia, Sweden, and the United States—the median share of industrial roundwood harvest in GDP during 1984 and 2001 was only 2.2 percent, with a range of 0.4-6.2 percent.

Cross-country indicators of corruption are available from several sources. Kaufmann et al. (1999a, 1999b), Arvind Jain (2001), and Johnston (2001) review these sources. We used indicators produced by PRS, which reports them to subscribers in its International Country Risk Guide (ICRG). PRS bases the ICRG indicators on its own research and analysis. In addition to an indicator labeled “Corruption,” it produces several other governance indicators. Stephen Knack and Philip Keefer (1995) were the first to use the ICRG indicators in cross-country economics research, and many studies have used them since, including several on corruption or related topics (e.g., Mauro, 1997; Anand Swamy, Young Lee, Omar Azfar, and Stephen Knack, 1999; Shang-Jin Wei, 2000; Johan Graf Lambsdorff, 2003; Bates et al., 2004). Their widespread use is despite several potential deficiencies of indicators produced by commercial risk-assessment firms: the firms might consult a small number of experts per country; the knowledge of the experts might vary across countries; and countries’ economic performance might bias the
experts’ opinions (Knack and Keefer, 1995; Mauro, 1995; Kaufmann et al. 1999a, 1999b; Swamy et al., 1999).

The ICRG indicators have several advantages that offset these potential shortcomings. One of the main ones is that they have broad country coverage (Swamy et al., 1999; Alberto Chong and Cesar Calderon, 2000; Knack, 2002), which reduces the risk of selection bias (Kaufmann et al., 1999a; Johnston, 2001). Several studies also argue that indicators produced by commercial firms must provide reasonably accurate cross-country information in view of the high subscription fees that their clients are willing to pay (Mauro, 1995; Ades and Di Tella, 1997, 1999; Kaufmann et al., 1999b). Another advantage is that the ICRG indicators are available for a relatively long time period, 1984 to the present (Chong and Calderon, 2000; Johnston, 2001). Their length is an important advantage for panel studies such as ours. Moreover, they are more consistent over time than Transparency International’s well-known Corruption Perceptions Index, which is an amalgam of indicators from different sources that change from year to year (Lambsdorff, 2004; Rose-Ackerman, 2004). Transparency International does not use PRS as one of its sources, but its reason signals an advantage of the ICRG corruption indicator for our study: the ICRG index “does not determine a country’s level of corruption [per se] but the political risk involved in corruption” (Lambsdorff, 2004, p. 2). As discussed in Section I, both the Hotelling and investment effects depend on the combination of corruption with political risk.

We used the ICRG indicators to construct two versions of CORRUPTION. The first was the “Corruption” indicator itself. This indicator is a rating from 0 to 6, with 0 indicating the most corruption and 6 the least (i.e., the reverse of the order one might expect). We rescaled it to the interval from 0 to 1 by dividing the original data by 6. The other version was a composite
variable that included three other ICRG indicators in addition to “Corruption”: “Bureaucracy Quality,” “Law and Order,” and “Democratic Accountability.” These indicators measure aspects of governance that previous research has found are closely associated with corruption (Mauro, 1995; Caroline Van Rijckeghem and Beatrice S. Weder, 1997; Jain, 2001; Johnston, 2001; Lambsdorff, 2003; Rose-Ackerman, 2004). In our sample, the correlations of these three indicators with “Corruption” were 0.70, 0.68, and 0.66, respectively. Mauro (1995, p. 686) constructed a similar composite variable and considered it “to be a more precise measure of corruption than the corruption index on its own.” As with “Corruption,” higher scores indicate better governance, and we converted all to a 0-1 interval. We formed the composite variable by taking the simple average of the four indicators.\footnote{Many previous studies have averaged, or equivalently, summed governance indicators, with the rationale being that averaging reduces measurement error if the indicators pertain to similar underlying concepts of governance and have independent errors (David Wheeler and Ashoka Mody, 1992; Knack and Keefer, 1995; Mauro, 1995, 1997; Chong and Calderon, 2002; Knack, 2002).}

\section*{C. Variables other than CORRUPTION}

HARVEST is the annual production of industrial roundwood in physical units (cubic meters, m\textsuperscript{3}), drawn FAOSTAT-Forestry.\footnote{Industrial roundwood is a broad category that encompasses sawlogs, veneer logs, and pulpwood. It excludes fuelwood, which is a fundamentally different commodity that is harvested mainly by households, not commercial logging companies.} FOREST is total forest area within a country, in hectares. FAO (2001a) provides estimates for 1990 and 2000. It defines ‘total forest’ as the sum of natural forests plus forest
plantations. We interpolated estimates for other years by fitting an exponential curve to the two observations for each country.

We obtained estimates of DENSITY—specifically, “total volume over bark of living trees above 10 cm diameter at breast height,” measured in m$^3$/ha—for the same two years from two other FAO reports (FAO 1995, 2001b). We interpolated the estimates for other years.

For LOG PRICE we used the export unit value for industrial roundwood. FAOSTAT-Forestry provides data on the quantity (in m$^3$) and value (in US$) of industrial roundwood exports for a large set of countries. For countries with few or no exports or with missing data, we used the export unit value for other countries in the same region as defined by FAO (1995). For Japan, which is a major timber importer and a small producer, we used the import unit value. We converted all unit values to real terms by using each country’s dollar-denominated GDP deflator.

For OIL PRICE we used the price on the world spot market, which is denominated in US$, as reported by the IMF’s International Financial Statistics database. This price does not vary in nominal terms across countries. As with roundwood price, we deflated it using each country’s GDP deflator, so it does vary in real terms.

For INTEREST RATE we used the real lending rate as reported by the World Bank in its World Development Indicators database.

D. Estimation Issues

Some authors have argued that economywide institutional variables are relatively stable over time and thus lose their explanatory power in fixed effects models (Knack and Keefer, 1995; Ades and DiTella, 1997; Edward B. Barbier and Joanne C. Burgess, 2001). To address this concern we analyzed not only the full sample of countries but also two subsamples that
excluded countries with negligible variation in the institutional variables. We formed the subsamples by excluding countries for which the coefficient of variation of the “Governance” variable during 1984-2001 was less than a specified value (10 percent or 25 percent). Institutional variables tend to vary more for developing countries than for developed countries, and so we also analyzed those subsamples separately. We also analyzed a subsample that included just the largest timber-producing countries, to control for the possibility that the forest sector does not attract political interest if it is too small. Countries in this subsample were ones whose mean harvests during the sample period were above the sample-wide median value.

To avoid endogeneity, we lagged the forest area and density variables one period. The global forest sector is highly competitive, with no country exerting substantial market power, so we do not expect significant endogeneity between a country’s timber harvest and the international price of its industrial roundwood.

All the results reported in the next section refer to fixed-effects estimates, with standard errors computed using the Newey-West variance estimator to correct for heteroskedasticity across countries. The Newey-West standard errors did not differ much from the uncorrected ones.

### III. Results

Tables 1 and 2 present our estimation results for Equation (16). The results in Table 1 show the effects of the definition of the CORRUPTION variable (the ICRG “Corruption” indicator vs. the composite governance variable) and the specification of the regression equation (linear vs. quadratic treatment of CORRUPTION; inclusion of other political and socioeconomic indicators). The results in Table 2 show the effects of the definition of the sample (developed vs.
developing countries, etc.). Collectively, the results indicate that corruption has a nonlinear impact on timber harvest, which is consistent with our theory. The investment effect dominates when corruption is high, and the Hotelling effect dominates when corruption is low. Support for this finding is stronger when corruption is measured by the composite governance variable and when the sample is limited to developing countries.

A. Effects of Definition of the CORRUPTION Variable

As a benchmark, the first column in Table 1 corresponds to a neoclassical timber supply specification that excludes any corruption indicator. All the coefficient estimates except the one for FOREST have the expected signs, and all except DENSITY are significant at the 5-percent level or better. Given that all the variables except the interest rate are expressed in logarithmic form, they can be interpreted as elasticities. Short-run timber supply is inelastic with respect to roundwood price, which is consistent with previous forest economics studies (Clark S. Binkley and Dennis P. Dykstra, 1987). The negative coefficient on forest area has at least two possible explanations. One is omitted variables bias caused by the exclusion of unit fixed costs, which we mentioned earlier. The other is a correlation between the evolution of the agricultural frontier and the development of timber harvesting infrastructure. We discuss this explanation below when we review results for the developed and developing country subsamples.

The remaining columns show the results for models that include CORRUPTION, as measured by either the ICRG “Corruption” indicator (the second and third columns) or the composite governance variable, labeled “Governance” (the fourth and fifth columns). The coefficient estimate on this variable is not significantly different from zero when “Corruption” is included in a purely linear fashion (the second column). In contrast, in the quadratic specifications (the third through fifth columns) the coefficient estimates on both the linear and
squared terms are mostly significant at a 5-percent level or better, and they show a consistent
sign pattern: the estimates are all positive on the linear term and all negative on the squared term.
This pattern indicates that a decrease in corruption (i.e., an increase in CORRUPTION) tends to
increase harvest in countries where corruption is relatively high but to decrease harvest in
countries where corruption is relatively low. These results suggest that the investment effect
dominates the Hotelling effect in highly corrupt countries—corruption drives away investment
that is required to harvest timber—while the reverse is true in cleaner countries.

The turning points and corruption elasticities are shown at the bottom of the table. The
turning points are nearly the same across the models, just above the midpoint of the 0-1 scale for
the CORRUPTION variables. The observations in the sample are split nearly equally above and
below the turning points, which suggests that the quadratic specification is indeed capturing a
turning point and not just a diminishing of the linear effect. This is confirmed by the elasticities,
which are positive when corruption is high (“Corruption” or “Governance” = 0.15) and negative
when corruption is low (“Corruption” or “Governance” = 0.85).20 The elasticities and the
magnitudes and significance levels of the estimated coefficients on which they are based are all
larger when CORRUPTION is measured by “Governance” instead of “Corruption.” This is the
outcome we would expect if, as previous authors have claimed, averaging the indicators reduces
the error in measuring corruption. Given that ICRG attempts to measure different aspects of
institutional quality with the four indicators, however, some of the increase in the elasticities
could also be due to the composite variable picking up effects of bureaucratic quality, law and
order, and democratic accountability that act independently of corruption. We therefore believe
that the impact of corruption per se on timber harvest lies somewhere between the lower
elasticity values in the third column and the higher values in last two columns.
It could be argued that there are other institutional factors not captured by even the broader “Governance” variable. Moreover, these factors might be correlated with one or more of the ICRG indicators that make up this composite variable. Their exclusion from the regression could be biasing the coefficients reported in the fourth column. To address this concern, we added to the model eight additional indicators reported by IRCG: government stability, a country’s investment profile, general socioeconomic conditions, extent of military and religious influence in politics, existence of internal and external conflicts, and ethnic fractionalization. Results are shown in the last column. The coefficients on the composite variable and its squared value decrease compared to those in the fourth column, but they retain their signs and significance levels. Wei (2000) and Jain (2001) have previously reported reductions in the coefficients on corruption variables when other institutional variables are added to regression models. Consistent with the Hotelling effect, countries with more stable governments have lower harvests; consistent with the investment effect, countries with better investment profiles have higher harvests. Socioeconomic conditions, which ICRG measures by using data on per capita GDP among other variables, do not have a statistically significant direct impact on harvests. This suggests that the “Governance” variable, which is positively correlated with per capita GDP, is not proxying for noninstitutional changes that occur as a result of economic development.

Among the other indicators, the highly significant and negative coefficient on the lack of military involvement in politics is notable: countries with political systems that are more free of military influence have lower harvests. This can be viewed as consistent with studies that have reported a link between natural resources and conflict (Rose-Ackerman, 2004; Collier and
Hoeffler, 2004), although the two indicators that directly measure the lack of conflict are positively signed and, in one case (external conflict), statistically significant.

B. Effects of Definition of Sample

In Table 2 we assess the robustness of the results to the definition of the sample used in the estimation of Equation (16). In all the regressions the corruption indicator used is the composite governance variable. The results for subsamples that exclude countries for which the coefficients of variation of this indicator were less than 10 or 25 percent are reported in the first and second columns, respectively. The results are generally similar to those obtained for the full sample (the fourth column of Table 1), but the coefficients on the composite variable and its squared value increase in absolute value as the variability of the indicators increases. This is what one would expect if limited variability in the indicators biases their coefficients toward zero in fixed effects models, as some authors have argued. The estimates of the turning point and the elasticity in more corrupt countries are not affected much, but the elasticity in less corrupt countries rises by approximately a third to a half. The Hotelling effect is evidently stronger than the results in the fourth column of Table 1 indicate.

The third and fourth columns show results for the subsamples of developing and developed countries. The coefficients on “Governance” and its square are highly significant and have the usual positive/negative sign pattern for developing countries, but they are insignificant for developed countries. The lack of significance in the latter case is probably due to the limited variability in the “Governance” variable over time within developed countries. Only two of the 66 countries in the subsample in the first column, and none of the 22 countries in the subsample in the second column, were developed countries. The high degree of overlap between the developing country subsample and the subsample of countries where the coefficient of variation
of “Governance” was at least 10 percent explains why the results in the third column are so similar to those in the first.22

The results for the developing and developed country subsamples also shed light on the reasons for the negative sign on the forest area variable in Table 1. Models of forest-sector development (e.g., Vincent and Binkley, 1992) predict that the expansion of the agricultural frontier in developing countries, which causes forest cover to fall, tends to be accompanied by an increase in timber harvests due to improved access as investment is made in roads and other infrastructure. We would thus expect the coefficient on FOREST to be negative when the sample is limited to developing countries, and that is what we see in the third column of Table 2. In contrast, in developed countries infrastructure in rural regions is already in place, and so trends in forest cover are not confounded by trends in infrastructure. FOREST reflects more purely the effect of forest cover on harvest in these countries, which we expect to be positive—as it is in the fourth column of Table 2. More than 75 percent of the countries in the full sample are developing, and so the results in Table 1 more closely mirror those for the developing country subsample.

The subsample of large roundwood producers includes a relatively high proportion of developed countries: 19 of the 48 countries in the subsample. It is thus not surprising that most of the coefficient estimates for this subsample, which are shown in the fifth column, lie between those for the developing and developed country subsamples. The coefficients on “Governance” and its square exhibit the usual positive/negative pattern and are both significant.

C. Simulated Impact of Hypothetical Reductions in Corruption

To assess the relative strength of the Hotelling and investment effects, we simulated the impact of a hypothetical reduction of corruption in major developing country timber producers as
of 2001 to the U.S. level. We used the “Governance” variable as the measure of CORRUPTION and the coefficient estimates from the developing country subsample in Table 2 to predict the impact of changes in this variable (and its squared value) on each country’s timber harvest. The countries included all the developing countries in the “Large producers” subsample that had complete data for 2001. The value of “Governance” in the U.S. in this year was 0.878 out of the maximum of 1. The values in the developing countries that we analyzed were not only all below this level (most by quite a margin), but moreover all but five were below the turning point of 0.56 from the developing country regression. For these countries, it was an open question whether harvests would rise or fall in response to the simulated reductions in corruption.

Table 3 shows the results of this counterfactual analysis. With one exception—the Democratic Republic of Congo—for all countries the predicted impacts are negative: reducing corruption would reduce timber harvests. This is consistent with conventional wisdom about the impacts of corruption on natural resource extraction; the Hotelling effect outweighs the investment effect. The predicted reductions in harvest are modest, however, around 10 percent for most countries. This is not surprising in view of the elasticity estimates in the third column of Table 2, which indicate that “Governance” has a less than proportionate impact on harvests both above and below the turning point. The positive impact for the Democratic Republic of Congo results from this country having by far the lowest value for “Governance” among the countries analyzed, 0.125.23 The investment effect thus has a greater impact in this country.

This counterfactual analysis ignores the fact that corruption might indirectly influence harvest through macroeconomic impacts on neoclassical variables in the supply function (e.g., the interest rate). Based on the results in Table 3, a large impact of corruption on timber harvests in developing countries would appear to depend on these indirect effects being large. This point
is underscored when one recalls our earlier point that the coefficients on the “Governance” variable and its square probably represent upper bounds on the impacts of corruption per se.

IV. Conclusions

This paper has made both theoretical and empirical contributions to knowledge on the impact of corruption on natural resource use. Theoretically, it distinguished between two opposing effects: (i) a depletion-accelerating “Hotelling effect” associated with the risk of losing office that leads corrupt officials to try to capture resource rents sooner rather than later, and (ii) a depletion-decelerating “investment effect” associated with the risk of losing extraction rights that increases companies’ risk-adjusted extraction costs. The first effect dominates in conventional wisdom, and a similar effect has been described by Robinson et al. (2003), albeit not in specific relation to corruption. Our analysis drew attention to the dependence of this effect on the combination of corruption and political insecurity. Corruption alone is not enough.

Our analysis demonstrated that the investment effect too depends on the combination of corruption and political insecurity, with the latter being linked to a technical condition on households’ response to changes in their rent share (in our model, changes in the amount of public services financed by resource taxes). Although much has previously been written about the depressing effects of corruption on investment, virtually none of it has been in a natural resources context. The best recent treatment of investment risk and natural resources is probably a study by Bohn and Deacon (2000), but their model did not include political actors or corruption.

The paper investigated the empirical impact of corruption on natural resource depletion by using panel data on national timber harvests, which had not been previously used in
corruption studies. We estimated a timber-supply model that included the standard explanatory variables in neoclassical timber-supply models as well as a measure of corruption for 97 countries during the period 1984-2001. We found that evidence of an impact of corruption on timber extraction is strongest for developing countries, where the impact is nonlinear and depends on a country’s level of corruption. This finding is consistent with our theoretical analysis: it suggests that the investment effect dominates in more corrupt countries, where corruption tends to reduce harvests, while the Hotelling effect dominates in less corrupt countries, where corruption tends to raise harvests. Reducing corruption in a given country could thus either increase or decrease timber harvests, depending on the country’s initial level of corruption and the magnitude of the reduction. For a subsample of major developing country timber producers, we conducted a simulation analysis which found that the Hotelling effect would likely outweigh the investment effect for large reductions in corruption (all the way to the U.S. level): for the majority of the countries in the subsample, cleaning up the government would result in lower harvests. The reductions were, however, relatively modest, around 10 percent of 2001 harvests.

We found statistically significant evidence of an impact of corruption on timber harvests even though we did not use data on corruption in the forest sector itself. We instead used economywide corruption measures, which likely suffer from measurement error when used in a timber supply model. This error should tend to bias the coefficient estimates on the measures toward zero. On the other hand, we obtained the most significant econometric results when we used a composite measure that combined a corruption indicator with three other indicators that previous studies have found are closely associated with corruption: bureaucracy quality, law and order, and democratic accountability. Given its composite nature, this measure could be picking
up the independent effects of one or more of the other three indicators, not just corruption per se. Unless the measurement error problem just mentioned is severe, which anecdotal evidence suggests is not the case, then this is an additional reason to believe that corruption’s impact on timber harvests in developing countries is modest.
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Endnotes


2 Combining the two effects into a single model adds mathematical complexity without generating any additional economic insight.


4 In Bliss and Di Tella (1997), a corrupt official’s expected utility is linked to the probability that the bribes he demands cause some firms to shut down, not that he loses office.

5 Dixit et al. (1997, p. 763) observe that the government “may want to provide a high standard of living to enhance its reelection prospects, to keep the population sufficiently happy to prevent riots, and so forth.”

6 Grossman and Helpman (1994, p. 846) and Dixit et al. (1997, p. 766) demonstrate that rents are completely captured by the government if there are as few as two industry lobbies.

7 Studies by Andvig and Moene (1990) and Ehrlich and Lui (1999) are two notable exceptions, but neither considers natural resources.

8 Resource economics textbooks commonly use two-period models to establish basic dynamic results (e.g., John M. Hartwick and Nancy D. Olewiler, 1998, chapter 8).

9 $H$ is strictly positive—the Minister must allocate some rent to households—if and only if households’ responsiveness to changes in public services is above a threshold:

$$p' > \frac{\nu_i + pv_i e^{-r}}{v_i e^{-r}(\nu_i + v_i e^{-r})}$$

10 Note that although investment is fixed per hectare, its total amount varies with the number of hectares opened for resource extraction.

11 This is a difference compared to the model in Ades and DiTella (1997), in which firms know they will be able to produce in the second period but do not know whether they will have to pay bribes. In our model firms do not know whether they will be able to extract the resource in the second period, but they know that if they do extract it (i.e., if the Minister remains in office), then they will need to pay the bribes that they offered in the first period when they obtained extraction permits.

12 $H$ is strictly positive if and only if $p'$ exceeds the threshold value $p/v$.

13 This can be seen by substituting $P - c'$ for $v'$ in Equations (10) and (15).


15 Authors’ calculations.

16 Researchers can obtain these indicators at www.prsgroup.com/academic/academic.html.
Following Bates et al. (2004; see also Knack and Keefer, 1995, p. 212), we also formed a composite variable by taking the first principal component of the four indicators. Regression results differed little when we used this version instead of the mean. We also considered applying the aggregation methodology developed by Kauffmann et al. (1999a), but as one of the authors (Aart Kraay) pointed out to us in an e-mail message, application of this methodology to data from a single and relatively complete source such as PRS is essentially equivalent to using the first principal component.

The FAOSTAT-Forestry database is available online at faostat.fao.org/faostat/collections?subset=forestry.

Annual rates of diameter growth in tropical forests are on the order of 0.5 cm (S. Appanah and Gerd Weinland, 1990). At this rate, a newly germinated seed would require 20 years to reach the diameter threshold of FAO’s timber stock estimates. This is longer than our sample period and reinforces our earlier point that we are analyzing the depletion of existing stocks of timber.

The values of CORRUPTION chosen for calculating the elasticities are approximately one step away from the minimal and maximal values of the ICRG scale ($1/6 \approx 0.15; 5/6 \approx 0.85$).

We also attempted to control for unobserved time-varying factors in two less direct ways. First, we added fixed effects for years to the model in the fourth column of Table 1. The coefficients on the composite variable and its squared value retained their signs and significance levels, and their magnitudes were intermediate between those in the fourth and fifth columns of Table 1. Second, we estimated the model in the fourth column with a correction for first-order serial correlation. The coefficients on the composite variable and its square were not significantly different from those reported in the fourth column of Table 1.

Coefficient estimates in a subsample of just tropical developing countries had identical signs and similar magnitudes and significance levels to those in the larger (76 vs. 56 countries) subsample of all developing countries. Timber supply in developing countries thus does not appear to depend much on the type of forest (tropical or temperate).

The next lowest value was for Côte d’Ivoire, 0.284.

Countries that have been spotlighted in discussions of corruption in the forest sector, such as Indonesia and Cameroon, are also ones that PRS ranks as highly corrupt.
<table>
<thead>
<tr>
<th></th>
<th>Neoclassical</th>
<th>Corruption: Linear</th>
<th>Corruption: quadratic</th>
<th>Governance: quadratic</th>
<th>Governance: quadratic, with additional institutional variables</th>
</tr>
</thead>
<tbody>
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<td>Forest</td>
<td>-0.6120***</td>
<td>-0.6092***</td>
<td>-0.6121***</td>
<td>-0.4361***</td>
<td>-0.4047**</td>
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<td></td>
<td>(0.1686)</td>
<td>(0.1680)</td>
<td>(0.1685)</td>
<td>(0.1691)</td>
<td>(0.1731)</td>
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<tr>
<td>Density</td>
<td>0.0745*</td>
<td>0.1053***</td>
<td>0.1049***</td>
<td>0.1033***</td>
<td>0.1064***</td>
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<tr>
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<td>(0.0378)</td>
<td>(0.0381)</td>
<td>(0.0372)</td>
<td>(0.0350)</td>
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<td>Log price</td>
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<td>0.0504**</td>
<td>0.0551***</td>
<td>0.0548**</td>
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<td></td>
<td>(0.0217)</td>
<td>(0.0215)</td>
<td>(0.0215)</td>
<td>(0.0212)</td>
<td>(0.0211)</td>
</tr>
<tr>
<td>Oil price</td>
<td>-0.0927***</td>
<td>0.0792***</td>
<td>-0.0753**</td>
<td>-0.0740***</td>
<td>-0.0569*</td>
</tr>
<tr>
<td></td>
<td>(0.0300)</td>
<td>(0.0297)</td>
<td>(0.0298)</td>
<td>(0.0288)</td>
<td>(0.0310)</td>
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<td>0.0992**</td>
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<td>0.0913**</td>
<td>0.0850**</td>
<td>0.0976***</td>
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<td></td>
<td>(0.0441)</td>
<td>(0.0403)</td>
<td>(0.0389)</td>
<td>(0.0371)</td>
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<td>Lower corruption</td>
<td>0.0218</td>
<td>0.4518*</td>
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<tr>
<td></td>
<td>(0.0781)</td>
<td>(0.2500)</td>
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<td></td>
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</tr>
<tr>
<td>Lower corruption, squared</td>
<td>-0.4174**</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>(0.2071)</td>
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</tr>
<tr>
<td>Better governance</td>
<td></td>
<td>1.4605***</td>
<td></td>
<td>1.1458***</td>
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<td>(0.3767)</td>
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<td>Better governance, squared</td>
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<td>-1.2317***</td>
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<td>-1.1229***</td>
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<tr>
<td></td>
<td></td>
<td>(0.2996)</td>
<td></td>
<td>(0.2921)</td>
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<td>More government stability</td>
<td></td>
<td></td>
<td></td>
<td>-0.3285***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.0792)</td>
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<td>Better investment profile</td>
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<td></td>
<td>0.4016***</td>
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<td></td>
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<td></td>
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<td>(0.0984)</td>
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<tr>
<td>Better socioeconomic conditions</td>
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<td></td>
<td></td>
<td>-0.0953</td>
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<tr>
<td></td>
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<td>(0.0828)</td>
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</tr>
<tr>
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<td></td>
<td></td>
<td>0.2135**</td>
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<td></td>
<td>(0.0868)</td>
<td></td>
</tr>
<tr>
<td>Less internal conflict</td>
<td></td>
<td></td>
<td></td>
<td>0.1228</td>
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<td></td>
<td></td>
<td></td>
<td>(0.1180)</td>
<td></td>
</tr>
<tr>
<td>Less religion in politics</td>
<td></td>
<td></td>
<td></td>
<td>0.3091***</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.1115)</td>
<td></td>
</tr>
<tr>
<td>Less ethnic fractionalism</td>
<td></td>
<td></td>
<td></td>
<td>0.0690</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.0880)</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>15.80***</td>
<td>15.59***</td>
<td>15.50***</td>
<td>13.99***</td>
<td>13.48***</td>
</tr>
<tr>
<td></td>
<td>(1.21)</td>
<td>(1.20)</td>
<td>(1.21)</td>
<td>(1.25)</td>
<td>(1.28)</td>
</tr>
<tr>
<td>N</td>
<td>1399</td>
<td>1391</td>
<td>1391</td>
<td>1391</td>
<td>1390</td>
</tr>
<tr>
<td>n</td>
<td>97</td>
<td>97</td>
<td>97</td>
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Table 1—Impact of Corruption and Other Governance Indicators on Timber Harvest

a
<table>
<thead>
<tr>
<th>Turning point</th>
<th>--</th>
<th>--</th>
<th>0.54</th>
<th>0.59</th>
<th>0.51</th>
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<tbody>
<tr>
<td>Elasticity (CORRUPTION = 0.15)</td>
<td>--</td>
<td>--</td>
<td>0.05</td>
<td>0.16</td>
<td>0.12</td>
</tr>
<tr>
<td>Elasticity (CORRUPTION = 0.85)</td>
<td>--</td>
<td>--</td>
<td>-0.22</td>
<td>-0.54</td>
<td>-0.65</td>
</tr>
</tbody>
</table>

*a The dependent variable in all regressions is the natural logarithm of annual timber harvest. All explanatory variables except the interest rate and governance indicators are also in logarithms. All regressions include country dummies (fixed effects). Standard errors (computed using the Newey-West correction) are in parentheses; *, **, *** denote significance at 10%, 5%, and 1% levels, respectively. N = number of observations; n = number of countries.*
<table>
<thead>
<tr>
<th></th>
<th>Variation ≥ 10%</th>
<th>Variation ≥ 25%</th>
<th>Developing Countries</th>
<th>Developed Countries</th>
<th>Large Producers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>-0.6511***</td>
<td>0.4427</td>
<td>-0.5740***</td>
<td>1.1746***</td>
<td>1.0297***</td>
</tr>
<tr>
<td></td>
<td>(0.1700)</td>
<td>(0.3327)</td>
<td>(0.1779)</td>
<td>(0.2781)</td>
<td>(0.2455)</td>
</tr>
<tr>
<td>Density</td>
<td>0.1265***</td>
<td>0.4187***</td>
<td>0.0914**</td>
<td>0.2216**</td>
<td>0.0483</td>
</tr>
<tr>
<td></td>
<td>(0.0382)</td>
<td>(0.0704)</td>
<td>(0.0392)</td>
<td>(0.0882)</td>
<td>(0.0411)</td>
</tr>
<tr>
<td>Log price</td>
<td>0.0609**</td>
<td>0.0072</td>
<td>0.0618**</td>
<td>-0.0171</td>
<td>0.0453**</td>
</tr>
<tr>
<td></td>
<td>(0.0265)</td>
<td>(0.0595)</td>
<td>(0.0251)</td>
<td>(0.0279)</td>
<td>(0.0187)</td>
</tr>
<tr>
<td>Oil price</td>
<td>-0.0710*</td>
<td>-0.0546</td>
<td>-0.0974**</td>
<td>0.0325</td>
<td>-0.0135</td>
</tr>
<tr>
<td></td>
<td>(0.0427)</td>
<td>(0.0707)</td>
<td>(0.0434)</td>
<td>(0.0269)</td>
<td>(0.0277)</td>
</tr>
<tr>
<td>Interest rate</td>
<td>0.0651**</td>
<td>0.3186***</td>
<td>0.0818**</td>
<td>0.2431</td>
<td>0.3408**</td>
</tr>
<tr>
<td></td>
<td>(0.0296)</td>
<td>(0.1139)</td>
<td>(0.0358)</td>
<td>(0.4474)</td>
<td>(0.1405)</td>
</tr>
<tr>
<td>Better governance</td>
<td>1.5152***</td>
<td>1.6865***</td>
<td>1.5700***</td>
<td>-1.4145</td>
<td>1.4782***</td>
</tr>
<tr>
<td></td>
<td>(0.4172)</td>
<td>(0.5571)</td>
<td>(0.4189)</td>
<td>(2.6794)</td>
<td>(0.4229)</td>
</tr>
<tr>
<td>Better governance,</td>
<td>-1.3831***</td>
<td>-1.5587**</td>
<td>-1.4044***</td>
<td>0.7243</td>
<td>-1.1198***</td>
</tr>
<tr>
<td>squared</td>
<td>(0.3784)</td>
<td>(0.7470)</td>
<td>(0.3792)</td>
<td>(1.5372)</td>
<td>(0.3464)</td>
</tr>
<tr>
<td>Constant</td>
<td>15.39***</td>
<td>5.6725***</td>
<td>15.07***</td>
<td>3.89</td>
<td>7.60***</td>
</tr>
<tr>
<td></td>
<td>(1.28)</td>
<td>(1.49)</td>
<td>(1.32)</td>
<td>(2.80)</td>
<td>(1.19)</td>
</tr>
</tbody>
</table>

|                      |                |                |                      |                    |                 |
| $N$                  | 923            | 303            | 1034                 | 357                | 721             |
| $n$                  | 66             | 22             | 76                   | 21                 | 48              |

Turning point
Elasticity
(“Governance” = 0.15)

-0.55 0.54 0.56 0.98 0.66

Elasticity
(“Governance” = 0.85)

-0.17 0.18 0.17 -0.18 0.17

-0.71 -0.82 -0.69 -0.16 -0.36

---

Table 2—Effects of the Definition of the Sample

---

$^a$ See notes for Table 1.
<table>
<thead>
<tr>
<th>Country</th>
<th>Change in harvest if 2001 “Governance” improved to U.S. levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congo (Democratic Republic)</td>
<td>+12.9%</td>
</tr>
<tr>
<td>Côte d'Ivoire</td>
<td>-3.7%</td>
</tr>
<tr>
<td>Cameroon</td>
<td>-5.6%</td>
</tr>
<tr>
<td>Nigeria</td>
<td>-7.1%</td>
</tr>
<tr>
<td>Paraguay</td>
<td>-7.7%</td>
</tr>
<tr>
<td>China</td>
<td>-9.1%</td>
</tr>
<tr>
<td>Colombia</td>
<td>-9.1%</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>-9.5%</td>
</tr>
<tr>
<td>Chile</td>
<td>-9.8%</td>
</tr>
<tr>
<td>Argentina</td>
<td>-10.5%</td>
</tr>
<tr>
<td>Vietnam</td>
<td>-10.6%</td>
</tr>
<tr>
<td>Gabon</td>
<td>-10.9%</td>
</tr>
<tr>
<td>Kenya</td>
<td>-10.9%</td>
</tr>
<tr>
<td>India</td>
<td>-11.0%</td>
</tr>
<tr>
<td>Indonesia</td>
<td>-11.5%</td>
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<tr>
<td>Mexico</td>
<td>-12.0%</td>
</tr>
<tr>
<td>Uganda</td>
<td>-12.1%</td>
</tr>
<tr>
<td>Brazil</td>
<td>-12.8%</td>
</tr>
<tr>
<td>Malaysia</td>
<td>-13.0%</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>-13.2%</td>
</tr>
<tr>
<td>Tanzania</td>
<td>-13.2%</td>
</tr>
<tr>
<td>Ecuador</td>
<td>-13.3%</td>
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<tr>
<td>Thailand</td>
<td>-13.3%</td>
</tr>
<tr>
<td>Philippines</td>
<td>-13.4%</td>
</tr>
</tbody>
</table>
Figure 1. Hotelling effect.
Figure 2. Investment effect.