Deforestation and the Rule of Law in a Cross-Section of Countries

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Robert T. Deacon

ABSTRACT. *Relationships between deforestation and population pressure, income growth, and insecure property rights are examined with data from 120 countries. Insecure property rights are hypothesized to arise from two sources: government instability or inability to enforce ownership and an absence of government accountability. The former source is captured by measures of general lawlessness such as guerrilla warfare, revolution, and frequent constitutional change. The latter is proxied by variables indicating the type of government executive, frequency of political purges, and the existence of an elected legislature. General support is indicated for the property rights hypothesis and for the effects of population growth.* (*JEL* Q23, O13)

I. INTRODUCTION

The use of forests and other natural resources in developing countries has received growing attention from environmentalists, the media, and government decision makers. Concern for forests, particularly tropical forests, stems both from the recent recognition that they provide critical services to host nations and worldwide, and from reports that global forest cover is shrinking. Many observers have attributed this shrinkage to population growth, the process of economic development, and misguided government policies. Much of the economic literature on deforestation stresses different factors—the importance of property rights and the role of ownership security in promoting conservation of forests and other natural assets.[1] This paper examines these hypotheses empirically by testing for relationships between deforestation and three possible causes: population pressure, growth in income, and insecure property rights as reflected in measurable legal and political attributes of countries. While models of the underlying processes causing deforestation are suggested in the text, none are developed rigorously. Rather, the intent is to present descriptive empirical results with the hope that they will help guide the development of better specified models and further empirical tests in the future.

Concern over the conversion of forests to cropland, pasture, and wasteland stems partly from the role of forests in global warming. Forests provide a sink for greenhouse gases. The process of deforestation often involves burning the standing biomass which causes the immediate atmospheric release of stored carbon. Forests also provide habitat for diverse life forms and contain a vast store of genetic information. Tropical forests are estimated to contain more than half of the world's species and only a small fraction of these have been studied to date for possibly useful compounds (Fisher and Hanemann, 1991). The genetic material in these organisms may yield new pharmaceuticals, hybrid plants, and pest controls (Sedjo 1992). In addition, forests contribute to water and nutrient cycling and provide purely private services to those who inhabit them (Peters, Gentry, and Mendelsohn 1989). The rapid conversion of forests during the last two decades—at rates exceeding 3 percent per

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[1]See Deacon (forthcoming), Mendelsohn (1991), Sedjo (1991), and Hyde, Mendelsohn, and Sedjo (1990).

year in some countries—accounts for the timing of concern.

The causes of deforestation are not well understood. Popular discussions often mistake associated effects and proximate causes for underlying forces (Panayotou 1990). Deforestation in developing countries is sometimes attributed to slash and burn agriculture, logging, and demands for fuel wood, fodder, and forest products. Yet temperate forests in many developed countries also face growing demand for forest products, logging activity, and agricultural competition for land, but generally are not experiencing the rapid forest depletion and land degradation found in the developing world.

The empirical contribution of economics to understanding deforestation presently is modest, but growing. Although several case studies of deforestation have been carried out in individual countries, few have developed empirical tests (Panayotou 1990). Notable exceptions are Panayotou and Sungsuwan (1989) on deforestation in Thailand, Lopez (1992) on the use of bush-fallow biomass in the Ivory Coast, and Southgate, Sierra, and Brown (1991) on deforestation in Ecuador. Two other studies have examined the relationship between debt and deforestation rates (Kahn and MacDonald 1991; Gullison and Losos 1992) and Pearce and Bann (1993) summarize results from additional unpublished work.

Among these, Southgate, Sierra, and Brown (1991) have examined the effect of ownership security and found that security of tenure, as measured by the prevalence of adjudicated land claims, is negatively related to deforestation rates.[2] In addition, there is ample case study evidence that enforcement of property rights is lacking in countries experiencing rapid deforestation. Leases to harvest from government forests in developing countries often are of very short duration so the harvester's self-interest does not provide sufficient incentive to conserve the economic value of the forest. Governments could of course encourage conservation on forests they own by closely controlling the harvest and regeneration practices of concessionaires. However, the associated costs and benefits are such that they seldom choose to do so (Repetto et al. 1989, 23; Boado 1988, 176, 186–87).

The present paper examines this property rights hypothesis indirectly, by testing for associations between deforestation and measures of political turmoil and repression. The potential role of these political factors in deforestation is summarized here and a more detailed discussion is presented in Section V. Conserving a forest to yield a stream of output in future years rather than consuming it immediately is an act of investment. Intuitively, investors will not forego current consumption for a future return without some assurance that the future benefit will be received by the party who makes the initial sacrifice. Such assurances normally result from legal contracts and the force of reputation. When legal and political institutions are volatile or predatory, the degree of assurance is lowered and the incentive to invest is diminished. The empirical analysis that follows tests for relationships between changes in forest cover and relevant political factors using data from a cross section of 120 countries.

As used here, deforestation is simply defined as a reduction in the land area covered by forests, using Food and Agriculture Organization (FAO) definitions of forested land (FAO 1988). To motivate the empirical results presented later in the paper the forest biomass is regarded as capital, and all deforestation is viewed as a change in land use from a more capital intensive to less capital intensive activity. Clearly, this characterization is simplified, and is undoubtedly inaccurate in specific instances. For example, when forestland is converted to mechanized, irrigated, high-yield agriculture of the sort practiced widely in developed countries, the value of capital per acre may well increase. Other things equal,

[2]Others have examined related hypotheses. Alston, Libecap, and Schneider (1994) have studied land titling and agricultural investments in two regions in Brazil. Anderson and Lueck (1992) present evidence on agricultural productivity for different ownership regimes on U.S. Indian reservations.

more secure ownership may well favor the conversion of some forested parcels in such circumstances. This description does not generally apply to the regions presently experiencing rapid forest conversion, however. Typically these are developing economies and forest conversion means burning the biomass, which clears the land and releases nutrients to the soil to support unmechanized, subsistence agriculture. Viewing deforestation as a reduction in capital intensity seems a safer generalization in this context. It is worth reiterating, however, that this view is adopted mainly for expositional purposes, to help organize the presentation of data and to provide straightforward hypotheses to test.

Searching for links between capital formation and political factors has precedent in recent work on "endogenous growth" theory, a line of research that stresses the microeconomic foundations of economic development.[3] In a cross-section study intended to test the convergence hypothesis of neoclassical growth theory, Barro (1991) found that measures of political turmoil have a significant negative association with rates of growth and investment in a cross section of countries, suggesting the effect of poorly defined property rights in volatile political regimes. He also recognized that the arrow of causation might point in the opposite direction, from income growth and high levels of investment, which create a sense of optimism and well-being, to domestic tranquillity. Persson and Tabellini (1990) examined this phenomenon in more depth, however, and found no evidence to support this possibility. Other studies in this general vein are Ozler and Rodrik (1992) and Alesina et al. (1991). The more traditional development literature is also suggestive. After surveying a broad array of quantitative and qualitative evidence, Reynolds (1983, 944, 963–64) found that growth in investment and per-capita income come only *after* stability is established, typically following a significant political event such as a change in government regime.

A parallel hypothesis for "forest capital" is examined by testing for empirical relationships between deforestation rates and a set of political indicators chosen to reflect ownership security. The data developed for these tests are also used to test two other commonly held beliefs on the process of deforestation—first that it results primarily from population growth and second that it is a product of increases in measured national income. Each of these hypotheses is examined in more detail as tests are presented.

II. EMPIRICAL APPROACH AND DATA USED

The empirical approach postulates that *levels* of forest biomass, B, are related to *levels* of socioeconomic factors, Z, such as population, income, and ownership security, and to environmental factors, E, such as temperature, rainfall, and soil conditions. The function is assumed separable and is written

$$B_{i,t} = G(E_i)F(Z_{i,t}; \beta), \quad [1]$$

where i and t index countries and years and β is a parameter vector. Notice that environmental conditions are assumed constant in each country. Two problems prevent direct estimation of this relationship in levels. First, the environmental indicators available for individual countries are limited in number and are reported for only a subset of the countries for which forest cover data are reported.[4] Second, available data identify only the *land area* classified as forest in each country, A, not the forest biomass. The approach to these problems is explained next; the practical result is a specification in which the percentage rate of deforestation is the dependent variable examined.

Area and biomass are related by $B_{i,t} = c_i A_{i,t}$, where c_i is biomass per acre of forest

[3]Romer (1989) surveys this literature.

[4]World Resources Institute (1992) reports the percent of land area that is classified as arid, semiarid, humid, cold, tropical, and so forth. If merged with data on 1980 forest cover this would limit the number of countries in the sample to 87.

in country i. Substituting this into [1] gives an expression in terms of forest area

$$A_{i,t} = [G(E_i)/c_i]F(Z_{i,t}; \beta), \quad [2]$$

Assuming c_i and E_i are functions of unchanging environmental conditions, their influence can be eliminated by taking logs of [2] and first differencing between two time periods. The result is

$$D_i \doteq \log[F(Z_{i,t-1}; \beta_{t-1})] - \log[F(Z_{i,t}; \beta_t)] \quad [3]$$

where $D_i = [\log(A_{i,t-1}) - \log[A_{i,t})]$ is the proportional deforestation rate in country i, the change in the logarithm of forest area between $t - 1$ and t. The coefficient vector is allowed to differ between years in anticipation of results presented later.[5]

If $F(\cdot)$ is linear in logs and the estimates satisfy $\beta_0 = \beta_1$, the model simplifies to a linear regression of log changes in socioeconomic factors on the proportionate rate of deforestation,

$$D_i = \beta[\log(Z_{i,t-1}) - \log(Z_{i,t})]. \quad [3a]$$

If $F(\cdot)$ is linear in logs but the coefficient vectors are unequal, the estimating model is a regression of current and lagged values of socioeconomic terms on the deforestation rate,

$$D_i = \beta_{t-1}\log(Z_{i,t-1}) - \beta_t\log(Z_{i,t}). \quad [3b]$$

If $F(\cdot)$ itself contains lagged Z terms, [3a] will include lagged first-differences of socioeconomic variables on the right-hand side and [3b] will include additional lags of Z in levels.[6]

This empirical approach requires two years of data on forest cover. The primary source of forest cover data is *An Interim Report on the State of Forest Resources in the Developing Countries* (FAO 1988). This source provides data on "total forest" cover for 129 countries in 1980 and 84 countries in 1985. Total forest includes land area covered by both closed and open forests.[7] A secondary source, FAO's *Production Yearbook,* reports "forest and woodland area," defined as land area under natural or planted stands of trees plus logged-over area that will be reforested in the near future. This source is available annually for most countries.

The *Interim Report* is considered the more reliable of the two and hence is used as the primary source of data on forest cover. The fact that this series is unavailable for many countries in 1985 is a drawback, however. In order to extend it, a statistical relationship between *total forest* and *forest and woodland area* was estimated using data on 84 countries for which both series are available. The estimated equation was then used to predict total forest cover in 1985 for the missing observations. The form of the equation used to predict total forest is motivated by postulating a general functional relationship between total forest, T, and forest and woodland area, w. This relationship, denoted $T(w)$, is then expressed as a second-order Taylor series expansion of T around 1980 values

$$T_1 = T_0 + T'(w_1 - w_0) + (T''/2)(w_1 - w_0)^2,$$

where 0 and 1 represent values in 1980 and 1985. Ordinary least squares regression yielded the following estimates, with standard errors in parentheses,

[5]There are several reasons why the coefficients might differ between years. Worldwide recognition of deforestation as an environmental issue rose dramatically between 1980 and 1985 and developing country governments came under increased pressure to exercise control. At the same time the World Bank and other lending agencies came under scrutiny for allegedly financing projects that accelerated deforestation. Hence, their lending practices may have changed between these years.

[6]This specification implies that the proportional rate of deforestation in a given time interval is independent of the initial level of forest cover. If this seems restrictive, it is worth noting that an alternative specification was examined in which the change in forested area is the dependent variable and initial forest acreage is included as a regressor. The estimated effects of socioeconomic factors in deforestation were very similar to those reported here.

[7]A closed forest includes broad-leaved, coniferous, and bamboo forests, with tree crown cover exceeding 20 percent of the land. An open forest consists of mixed forest/grasslands with at least 10 percent tree cover. See World Resources Institute (1992, 292) for further details on these definitions.

$$T_1 = .9995T_0 + 1.2451(w_1 - w_0) + 10.2301(w_1 - w_0)^2 \quad R^2 = .998$$
$$\quad\;\; (.0056) \qquad (.1510) \qquad\qquad (1.9863) \qquad\qquad N = 84$$

where T and w are measured as fractions of the land area of countries. The high R^2 is of course due to the close correlation between T_0 and T_1. As the other coefficient estimates clearly indicate, however, changes in total forest are strongly related to changes in forest and woodland area.

In addition, measures of population, national income, and country specific indicators of the rule of law—variables that indicate the degree of political stability and popular representation—are needed. Data on population were taken from Banks (1990) and data on income, actually gross domestic product, were taken from Summers and Heston (1991). Political/legal indicators were obtained from Banks (1990). Indicators of political and legal stability include frequencies of political assassinations, riots, major constitutional changes, guerrilla warfare, attempts at revolution, riots, and government regime changes. As explained later, measures of political representation were also examined, including type of government executive (military, elected, monarch), frequency of political purges, and existence of an elected legislature. These variables are defined more precisely in Section IV.

Table 1 lists the 120 countries examined, 20 of which are defined as "high income" by the World Bank. It also partitions the overall sample into two deforestation groups, depending on whether countries lost more or less than 10 percent of their 1980 forest cover during 1980–85. This sample excludes countries with less than 500,000 population or having less than 1 percent of land area covered by forests in 1980. It may seem surprising to see Brazil, Indonesia, and the Philippines included among low deforestation countries, as they often appear prominently in discussions of worldwide forest conversion. While these three countries account for large absolute areas of forest loss per year, this is partly due to the fact that the total forest areas in these countries are large. Their percentage deforestation rates ranged from 0.5–0.9 percent per year during 1980–85. By comparison, average annual deforestation rates in Afghanistan, Cote d'Ivoire, and Haiti were 3.7–5.0 percent during the same time span.

In what follows, each of the three hypotheses of interest is examined in isolation, by testing for associations between deforestation rates and, alternatively, population growth, income growth, and political attributes. These simple tests are useful for determining the sensitivity of results to the choice of sample, the exact definition and lag structure of determining variables, and so forth. These results are then used to formulate a more general model that allows for the presence of all three influences at once.

III. DEFORESTATION AND POPULATION GROWTH

Many cite population growth as the single most important cause of deforestation (Allen and Barnes 1985, 175; World Bank 1992, 26–29; World Rainforest Movement 1990, 78). Population growth often leads to migration to the forests by peasants seeking land to clear for subsistence farming. Population growth also increases fuel wood collection, which removes nutrients from the forest. If nutrient loss is sufficiently intense, the result is slowed regeneration and eventual degradation of forest cover.

Table 2 provides a simple test of this hypothesis, where the dependent variable is the proportionate rate of deforestation during 1980–85. Positive population growth is associated with deforestation but the effect is not immediate. Rather, the strongest association is with the rate of population increase five years earlier. In this simple model, a 1 percent increase in population during 1975–80 is associated with a proportionate forest cover reduction of 0.24–0.28 percent during 1980–85.[8]

[8]The effect of population growth was initially examined by estimating a model of form [3b], with D_i expressed as a linear function of population in 1985,

TABLE 1
COUNTRIES IN SAMPLE

High Deforestation	Low Deforestation		
Low and Middle Income Countries			
Afghanistan	Albania	German D. R.	Papua New Guinea
Costa Rica	Angola	Ghana	Paraguay
Cote d'Ivoire	Argentina	Greece	Peru
Ecuador	Bangladesh	Guatemala	Philippines
El Salvador	Benin	Guinea	Poland
Gambia	Bhutan	Guyana	Portugal
Guinea-Bissau	Bolivia	Hungary	Romania
Haiti	Botswana	India	Rwanda
Honduras	Brazil	Indonesia	Senegal
Iraq	Bulgaria	Iran	Sierra Leone
Jamaica	Burkina Faso	Kenya	Somalia
Lebanon	Burundi	Korea, North	Sudan
Liberia	Cambodia	Korea, South	Swaziland
Malawi	Cameroon	Lao P. D. R.	Tanzania
Nepal	Cent. African Rep.	Madagascar	Togo
Nicaragua	Chad	Malaysia	Trinidad and Tobago
Niger	Chile	Mali	Tunisia
Nigeria	China	Mauritius	Turkey
South Africa	Colombia	Mexico	Uganda
Sri Lanka	Congo	Mongolia	Uruguay
Syria	Cuba	Morocco	Venezuela
Thailand	Czechoslovakia	Mozambique	Vietnam
	Dominican Rep.	Myanmar	Yugoslavia
	Ethiopia	Namibia	Zaire
	Fiji	Pakistan	Zambia
	Gabon	Panama	Zimbabwe
High Income Countries			
Israel	Australia	F. R. Germany	Spain
	Austria	Ireland	Sweden
	Canada	Italy	Switzerland
	Cyprus	Japan	United Kingdom
	Denmark	Netherlands	United States
	Finland	New Zealand	
	France	Norway	

Note: Excludes countries with fewer than 500,000 population. See text for definitions.

The simple correlation between cross country population growth rates in 1975–80 and 1980–85 is fairly high, 0.86 in this sample. For this reason the model was reestimated with the 1980–85 population growth rate excluded. As the figures in the third and fourth columns indicate, this increases the significance of the lagged growth rate but has no appreciable effect on the coefficient estimates. The second and fourth columns of coefficients indicate that these results are largely unchanged when countries with relatively light forest cover are dropped from the sample.[9] The general tenor of these results—that deforestation is associated with lagged population growth—does not change appreciably when countries are separated by income levels. Reestimating these models with high income countries excluded yielded coefficients that are slightly smaller in algebraic value than those in Table 2, but the change is not significant. Surprisingly, perhaps, the

1980, 1975, and 1970. An F test revealed that this could be collapsed into a model of form [3a], which is what is reported in Table 2.

[9]The countries excluded are Afghanistan, Burundi, Haiti, Iran, Iraq, Israel, Kenya, Lebanon, Niger, Pakistan, South Africa, Syria, Tunisia, and Uruguay.

TABLE 2
DEFORESTATION AND POPULATION GROWTH
(ORDINARY LEAST SQUARES ESTIMATES)

Countries in Sample	All	Forest > 5%	All	Forest > 5%
Log change in population, 1980–85	−.0304	.0009	—	—
	(−0.17)	(0.01)		
Log change in population, 1975–80	.2593	.2815	.2357	.2814
	(1.52)	(2.01)	(2.55)	(3.34)
Log change in population, 1970–75	.0575	−.0221	.0544	−.0218
	(0.69)	(−0.20)	(0.67)	(−0.22)
Constant	.0274	.0188	.0270	.0188
	(2.27)	(1.08)	(2.30)	(1.82)
R^2	.08	.14	.08	.14
N	112	98	112	98

Notes: t-statistics in parentheses. The dependent variable is the 1980–1985 change in the logarithm of land area classified as forest. The heading "Forest > 5%" indicates that forest cover in 1980 exceeds 5 percent of the country's land area.

population growth coefficients are all larger in algebraic value when estimated for high income countries. That is, a given rate of population growth is associated with a higher deforestation rate if it occurs in a high income country than in a low income country. Again, the most signficant association is with population growth lagged five years.

IV. DEFORESTATION AND INCOME GROWTH

Growth in measured national income is often identified as an important correlate, and sometimes as a cause, of deforestation. This is implicit in discussions that attribute deforestation to economic development strategies that promote conversion of forests to plantation agriculture and the production of cash crops for export (World Rainforest Movement 1992, 41, ff.). It also appears at the heart of proposals to revise national income to appropriately incorporate the consumption of natural assets. Those who advocate such revisions point out that an important share of measured GNP, particularly in developing countries, is actually consumption of natural capital such as forests (see Repetto et al. 1989, 4–9; Solorzano et al. 1991).

Table 3 presents evidence relevant to this hypothesis. These simple correlation coefficients indicate that, if anything, the association between deforestation and growth in measured income is negative—rapid deforestation accompanies slow, or negative, measured economic growth. Experimentation with different samples indicates that this lack of association is robust. Although not shown in the table, a negative relationship between income growth and deforestation exists for high income countries as well.[10]

Of course this does not invalidate the proposition that some growth in measured income actually is consumption of forest capital. It may indicate, however, that any such relationship based on capital consumption is outweighed by the increase in demand for forest preservation that comes with increases in income. Alternatively, it may indicate the presence of a third factor that is positively related to both income growth and the maintenance of forest cover. A possible set of such factors is examined next.

[10]The economic growth hypothesis was initially tested by estimating regression equations of form [3b]. None of the equations or individual coefficient estimates approached statistical significance, however. Simple correlations are reported in Table 3 since they summarize the principal findings compactly.

TABLE 3
DEFORESTATION AND INCOME GROWTH (CORRELATION COEFFICIENTS)

	All Countries	Forest > 5%	Low and Middle Income
Log change in per-capita GDP, 1980–85	−.1776	−.1061	−.1423
Log change in per-capita GDP, 1975–80	−.0642	−.0890	−.0110
Log change in total GDP, 1980–85	−.0917	−.0044	−.1066
Log change in total GDP, 1975–80	.0380	.0227	.0349
N	105	92	85

Notes: Low and middle income countries are identified in Table 1. See note to Table 1 for other definitions.

V. DEFORESTATION, OWNERSHIP SECURITY, AND THE NATURE OF POLITICAL SYSTEMS

Forest cover is a form of capital that is productive in several land uses. Land continuously covered by forest can yield a sustained flow of minor forest products such as fruit, latex, rattan, oils, or grazing (Peters, Gentry, and Mendelsohn 1989). Alternatively, forested land can be harvested intermittently to obtain timber, in which case the standing biomass at any time is capital that enables future timber growth. If a forest is used for sustainable shifting cultivation, with relatively long fallow periods during which forest cover is allowed to increase, then the growing stock is a store of nutrients that can be harvested periodically. The latter two land uses are very similar. Both involve an investment period during which forest capital accumulates followed by harvest, either of timber or of nutrients for agriculture, and both allow the possibility for this cycle to be repeated indefinitely.

A Simple Model of Default Risk and Land Use

Poorly enforced ownership exposes standing forests and other kinds of capital to a form of confiscation or default risk and thereby discriminates against capital intensive land uses. Long fallow periods between harvests of nutrients are attractive only if the individual, family, or tribe has some assurance that a parcel of land and its forest cover will not be invaded by squatters, harvested by a timber company, or confiscated by a government official. The same point applies to land used to grow timber. Likewise, land that would be used to grow minor forest products if ownership were enforced might be deforested instead if ownership becomes insecure, in order to obtain timber or simply to make the land available for less capital intensive uses. In general, poorly defined ownership favors either the conversion of forested land to noncapital intensive permanent agriculture or its degeneration to wasteland.[11]

Mendelsohn (1991) formalized this point in a simple model of default risk. Each year the current occupant of a parcel of land faces a constant probability, λ, that his or her claim to the land and any capital on it will be lost due to theft, government confiscation, or a legal dispute. With λ assumed constant, the probability that no theft occurs over a period of t years is $(1 - \lambda)^t$. By assumption, any return the land and capital would earn in the future is completely lost to the owner if a theft occurs. Defining $\pi = -\log(1 - \lambda)$, the probability of no loss during a period of t years is $e^{-\pi t}$.

Next, consider three alternative land uses and examine the effect of confiscation risk on the use chosen for a given parcel of land. The first use, s, is the sustained harvest of minor forest products from a standing forest. It yields an annual return of R_s per acre. In this simple world, insecure

[11] An example is the conversion of much Southeast Asian land to *Imperata Cylintrica,* or "alang alang" (Panayotou and Sungsuwan 1989).

ownership causes the parcel's expected present value in use s to be $V_s = R_s/(r + \pi)$, where r is the risk free rate of interest. The second alternative is conversion to permanent agriculture, denoted a. This is modeled as a process that earns a return that decays exponentially over time as the soil's nutrients are depleted, $R_a(t) = R_a(0)e^{-at}$, where $R_a(0)$ is the return in the year the land is first cleared. The expected present value return in this use is $V_a = R_a(0)/(r + a + \pi)$. Clearly, an increase in π will cause the present value of use s to fall relative to use a.[12] Hence, a reduction in ownership security favors conversion of land from s to a.

The third use is for timber harvests or shifting agriculture, which yields a return of $R_f(t)$ if a harvest occurs after t years. The expected present value per acre in this use is $V_f = R_f(t)/(1 - e^{-(r+\pi)t})$. Here, π enters both the choice of rotation age and the present value calculation as an effective increase in the interest rate. An increase in π necessarily increases V_f/V_s and thus shifts land use toward f, which is the less forest intensive of these two uses.[13] Mendelsohn (1991) showed that increasing π causes V_a/V_f to rise when a is relatively large, that is, when soil depletion from agriculture is relatively rapid. Again, the effect of reduced ownership security is to shift land toward the less forest intensive use.

Even when the land use category remains unchanged, ownership insecurity favors less capital intensive production methods. When the land uses are timber or shifting cultivation with fallow periods this shows up in shorter rotations. In these cases the expected loss in any year, whether due to eviction, theft, or confiscation, is part of the cost of capital and acts like an increase in the interest rate. When rotations are shortened the average forest cover in any set of land parcels is reduced.[14]

The Role of Political Factors in Ownership Security

Insecure property rights, either to assets or income streams, might arise from two sorts of political circumstances. First, government may lack the power, stability, and popular support to enforce laws of property. Absent reliable third party enforcement and predictable legal interpretations of property claims, the individual's incentive to invest is weak. While this argument seems straightforward when applied to privately held property, a similar argument can be made for assets nominally owned by government. When government lacks the ability to enforce controls on how government forests are used they tend to be treated as free access resources. This is manifest in Latin America and elsewhere by the colonization of national parks and government forest reserves by squatters.

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[12]Note that $V_s/V_a = (R_s/R_a(0))(1 + a/(r + \pi))$, which is decreasing in π.

[13]This can be shown by differentiating $V_f/V_s = [R_f(t)/(1 - e^{-(r+\pi)t})]/[R_s/(r + \pi)]$ with respect to π and demonstrating that the result is necessarily positive for $t > 0$. Details are available from the author.

[14]Before moving to a discussion of political factors it is worth noting that increased variability in taxation or regulation can weaken the incentive to invest even when no confiscation occurs and the average or "expected" return to investment remains unchanged. Pindyck (1991) has shown that uncertainty over future returns causes potential investors to slow the rate of investment in cases where the cost of a project cannot be recovered once it is initiated. In effect, delaying the project has an option value since the potential investor can gain by learning about the future before committing. "Policy instability" can thus reduce investment even when no outright theft occurs, implying that forest cover might be reduced by political factors that increase the variance of an investment's return without affecting the mean. Allowing a parcel of cleared land to revert to forest cover is an investment project. The project's cost is the agricultural yield the land would earn if farmed and this cost cannot be recouped if the investor gets a "bad draw" on the investments' return. Delaying forest regeneration gives the investor an option on the project's cost, and the value of this option is greater the greater is the variance of the project's return. Hence, instability in tax or regulatory policy can delay investments in forest regeneration. Tax and regulatory policies presumably are less stable in countries that experience rapid shifts in government regime, or face the threat of such changes, particularly if these changes are not constrained by a predictable constitutional process. Thus, actual regime changes plus such precursors to change as riots, general strikes, and antigovernment demonstrations are possible indicators of this kind of instability.

Further, if the institutions of government are weak or short-lived, proposals for long-term investment in government-owned assets will lack credibility since the segments of society making the initial sacrifice will have no guarantee of receiving the ultimate reward. Measures of general lawlessness, guerrilla warfare, armed revolt, and rapid changes in laws or constitutions are used as empirical indicators of such instability.

Second, it is hypothesized that the average individual's ownership security tends to be weak in countries that are governed by the rule of individuals and dominant elites rather than the rule of law and anonymous institutions. In such circumstances, one's property claim may depend heavily on the favor of a specific individual or clique rather than the persistence of a set of political and legal institutions. If the clique is deposed, its allies may lose their property. For those who are not in favor with the ruling elite, property claims are even more problematic since those who control government may choose to enforce laws selectively and redistribute property toward themselves or their allies. Such redistribution need not be direct, it may take the form of opportunistic taxation or regulation. Accumulating capital in such circumstances may simply invite confiscation. Empirically assessing the degree to which a country is ruled by individuals as opposed to laws is approached by determining whether its governmental system exhibits attributes of popular representation, for example, whether its leaders are elected, whether a legislature exists, whether political opposition is tolerated, and so forth.

Empirical Results

This general set of hypotheses initially was tested in a very simple way. Data on the attributes of political and governmental systems were obtained in each country, and country averages were formed over 1980–85. These average political attributes were then compared for countries experiencing high versus low deforestation during 1980–85, using the sample of countries shown in Table 1. The ten variables selected to measure general lawlessness and governmental/legal instability are shown in Table 4. The mean number of political assassinations per million population is a measure of general lawlessness, and may also indicate government instability. Other variables are primarily indicators of instability in a given regime's grip on power or, as in the case of major constitutional changes, a measure of the frequency of changes in the basic legal structure regardless of regime.

All variables in Table 4 are defined in such a way that figures in the first column will exceed those in the second if the hypotheses is correct. This expectation is confirmed for nine of the ten measures. The differences are significant at 10 percent using a one-tailed test for frequencies of revolutions, guerrilla warfare, and major constitutional changes. Contrary to expectations, coups de'état are slightly more frequent in low deforestation countries, but the difference is small and insignificant. All high income countries were excluded in these comparisons. When high income countries are included the differences become much sharper: t-statistics rise for all comparisons except coups d'état, which falls to near zero, and six of the ten differences become significant at 10 percent.

The second set of tests concerns the effect of popular representation on deforestation. The variables used to measure representation in each country are defined in Table 5. The first three of these are self-explanatory. Regarding the fourth, the chief executive of government is a premier only if chosen by elected representatives. This indicates, jointly, that the selection process is democratic and that the legislative branch exercises substantial power, hence the degree of representation is high. Representation is thus weaker if the executive is not a premier. Frequent political purges indicate that opposition, and hence competition for political power, is not tolerated. Consequently, the first five measures are *larger* in less representative systems and are expected to be greater in high deforestation countries. The sixth, "Legisla-

TABLE 4

DEFORESTATION AND MEASURES OF LAWLESSNESS AND GOVERNMENTAL/LEGAL INSTABILITY (MEAN POLITICAL ATTRIBUTES BY DEFORESTATION RATE, 1980–1985)

	High Deforestation Countries, μ_H	Low Deforestation Countries, μ_L	t-statistic* H_0: $\mu_L < \mu_H$	$Pr > t$
Political assassinations**	.0822	.0264	0.94 (24)	.18
General strikes**	.0245	.0142	0.88 (34)	.19
Riots**	.0468	.0284	1.04 (28)	.15
Anti-gov't. demonstrations**	.0645	.0482	0.82 (49)	.21
Guerrilla warfare	.3333	.2051	1.31 (31)	.10
Revolutions	.3258	.1859	1.63 (29)	.06
Major government crises	.1439	.0684	1.08 (25)	.14
Coups d'état	.0303	.0384	0.39 (31)	.36
Major constitutional changes	.1136	.0705	1.41 (31)	.08
Government regime changes	.0727	.0436	1.08 (30)	.14
Number of countries	22	78	—	—

Source: A. S. Banks, *Cross-National Time-Series Data Archive,* SUNY Binghampton, 1990.

* t-statistic is for the one-tailed test H_0: $\mu_H \leq \mu_L$ versus H_a: $\mu_H > \mu_L$. Degrees of freedom are in parentheses.

** Per million population.

Notes: Excludes 20 countries classified as "high income" by the World Bank. A *high deforestation* country is one that lost at least 10 percent of the forest cover existing in 1980 during 1980–85. A *political assassination* is any politically motivated murder or attempted murder of a high government official or politician. A *general strike* is a strike of 1,000 or more workers aimed at national government policies or authority. A *riot* is any violent demonstration of more than 100 citizens involving the use of physical force. *Anti-government demonstrations* are peaceful gatherings of at least 100 people for the primary purpose of displaying opposition to government policies or authority. *Guerrilla warfare* is the presence of any armed activity, sabotage, or bombings carried on by independent bands of citizens or irregular forces and aimed at the overthrow of the present regime. A *revolution* is an attempted illegal or forced change in top government elite, or armed rebellion intended to gain independence from the central government. A *major government crisis* is a rapidly developing situation that threatens to bring the downfall of the present regime—excluding revolt aimed at such overthrow. A *coup d'etat* is a successful extraconstitutional or forced change in the top government elite and/or its effective control of the nation's power structure—including successful revolutions. *Major constitutional changes* reports the number of basic alterations in a state's constitutional structure, e.g., adoption of a new constitution that alters roles of different branches of government (minor constitutional amendments are excluded). A *government regime change* is any change in the type of regime, e.g., civilian, military, protectorate, in charge of government.

TABLE 5

DEFORESTATION AND INDICATORS OF NONREPRESENTATIVE GOVERNMENT (MEAN INDICATORS BY DEFORESTATION RATE, 1980–1985)

	High Deforestation Countries, μ_H	Low Deforestation Countries, μ_L	t-statistic* H_0: $\mu_L < \mu_H$	$Pr > t$
Government executive is military	.2424	.0940	1.80 (27)	.04
Nonelected executive	.4394	.3184	1.11 (33)	.14
No legislature exists	.1742	.1410	0.49 (36)	.31
Executive is not a premier	.6136	.4124	1.79 (36)	.04
Political purges	.0909	.0620	0.74 (30)	.23
Legislature is elected*	.7879	.8419	0.72 (35)	.24
Changes in executive*	.1136	.1624	1.16 (50)	.13
Number of countries	22	78	—	—

Source: A. S. Banks, *Cross-National Time-Series Data Archive,* SUNY Binghampton.

* t-statistic is for the one-tailed test H_0: $\mu_H \leq \mu_L$ versus H_a: $\mu_H > \mu_L$, except in tests involving *Legislature is elected* and *Changes in executive* where the inequalities are reversed.

Notes: Excludes 20 countries classified as "high income" by the World Bank. A *high deforestation* country is one experiencing a loss of forest cover during 1980–85 exceeding 10 percent of the amount existing in 1980. *Government executive is military* indicates that the individual who exercises primary influence in shaping the country's major internal and external decisions is in the armed services. *Executive is not a premier* indicates that the executive is not drawn from the legislature of a parliamentary democracy. A *purge* is the systematic elimination by jailing or execution of political opposition within the ranks of the regime or the opposition. *Legislature is elected* indicates that a legislature exists and that legislators are chosen either by direct or indirect election. *Changes in executive* are the number of times in a year that control of the executive changes to a new individual independent of the predecessor. Other measures are self-explanatory.

ture is elected,'' is expected to be *smaller* in less representative governments, and hence smaller in high deforestation countries. Regarding the last measure, frequent changes in executive might plausibly indicate competition in the executive branch. If so, such changes should be more common in low deforestation countries. Alternatively, more frequent executive change might signal greater instability in government policy and hence greater deforestation. The comparison in Table 5 supports the former hypothesis, although the difference is not highly significant.

To summarize the results obtained, all seven comparisons are as expected. Only two of the differences are significant at 10 percent, however, those for "military executive" and for "executive is not a premier." Again, the results become much sharper when high income countries are included. In this case four of the seven are significant at 10 percent.

The 17 political measures in Tables 4 and 5 clearly are not independent. To test their joint association with deforestation, a logit regression equation was estimated using the political measures as regressors and testing their joint ability to predict a categorical variable denoting high versus low deforestation countries. When all 17 measures are included and the sample includes all 120 countries, the chi square statistic indicates the regression is significant at a probability level of 0.02. All but four of the coefficients have signs that accord with the differences in means reported earlier, and none of the four with perverse signs approach significance. When high income countries are excluded, the probability of no relationship rises to 0.15. If variables with z statistics below 0.5 are excluded, however, the probability level falls to 0.02 and the number of perverse signs falls to one. Overall, then, the null hypothesis that these measures of political instability and nonrepresentation are not related to deforestation is rejected.

Comparisons of means do not directly indicate the strength of relationships between political factors and deforestation rates. The regression approach used earlier was employed to address this question. To test an association between deforestation and a specific political attribute, P, $\log(\cdot)$ from equation [3] is assumed to be a linear function of current and past levels of the attribute,

$$\log(F(Z_{i,t};\beta_t)) = \beta_t P_{i,t} + \gamma_t P_{i,t-1}.$$

Both current and lagged values are included because the relevant consideration is expectations about lawlessness and expectations may be revised gradually.

This yields a deforestation equation of form [3b]

$$\begin{aligned} D_i &= (\beta_{t-1}P_{i,t-1} + \gamma_{t-1}P_{i,t-2}) \\ &\quad - (\beta_t P_{i,t} + \gamma_t P_{i,t-1}) \\ &= -\beta_t P_{i,t} + (\beta_{t-1} - \gamma_t)P_{i,t-1} + \gamma_{t-1}P_{i,t-2}. \end{aligned}$$

The political measures cannot be expressed in logs because they often take on zero values. By hypothesis, β and γ are expected to be negative for political attributes that measure greater lawlessness and positive otherwise. Hence, the coefficients for $P_{i,t}$ and $P_{i,t-2}$ are expected to be positive and negative respectively, and the coefficient of $P_{i,t-1}$ is of ambiguous sign. The periods examined are five- and six-year blocks of time. D_i is the deforestation rate during 1980–85, $P_{i,t}$ is the mean of a country's political attribute during the same period, $P_{i,t-1}$ is the mean during 1975–79, and so forth.

Table 6 reports regression coefficients for this simple model, where the political attributes used are those found to have significant differences in means between high and low deforestation countries. Three sets of results are reported for three different samples of countries. All of the coefficients for *current* political attributes (1980–85) are of expected sign and most are significant at conventional levels. In most cases the coefficients are not highly sensitive to the sample used, although their signficance naturally tends to be greater in larger samples. The effect of guerrilla warfare and revolutions on deforestation appears to be smaller in heavily forested countries, although the difference is not significant. The explana-

TABLE 6
DEFORESTATION AND POLITICAL ATTRIBUTES (OLS REGRESSION COEFFICIENTS)

Sample	Full Sample	Low and Middle Income Countries	Low and Middle Income and Forest > 5%
Guerrilla warfare			
1980–85	.0706	.0569	.0267
	(2.77)	(2.09)	(1.10)
1975–79	−.0197	.0031	.0084
	(0.73)	(0.10)	(0.31)
1970–74	−.0086	−.0114	−.0105
	(1.19)	(1.53)	(1.51)
Prob > *F*	.02	.03	.28
Revolutions			
1980–85	.1028	.1054	.0680
	(3.88)	(3.87)	(2.62)
1975–79	−.0326	−.0334	−.0348
	(1.35)	(1.32)	(1.53)
1970–74	−.0271	−.0335	−.0244
	(1.22)	(1.49)	(1.17)
Prob > *F*	<.01	<.01	.06
Constitutional changes			
1980–85	.1220	.1036	.0984
	(2.21)	(1.79)	(1.87)
1975–79	−.0262	−.0364	−.0252
	(0.60)	(0.78)	(0.58)
1970–74	.0222	.0162	.0149
	(0.64)	(0.44)	(0.46)
Prob > *F*	.13	.28	.24
Military executive			
1980–85	.0465	.0413	.0376
	(1.57)	(1.36)	(1.40)
1975–79	.0199	.0193	.0176
	(0.54)	(0.51)	(0.52)
1970–74	−.0288	−.0339	−.0299
	(0.89)	(1.02)	(1.01)
Prob > *F*	.14	.23	.28
Executive is not a premier			
1980–85	.0303	.0299	.0367
	(2.47)	(2.21)	(3.15)
Prob > *F*	.01	.03	<.01

Note: Absolute values of *t*-statistics in parentheses.

tory power of these regressions is low, with R^2 values ranging from .04 and .15. Most are significant at 5 percent, however.

The equation for "executive is not a premier" includes only the current value of this indicator since current and lagged values of this variable are highly correlated. Simple correlations between deforestation and all three measures of this variable (the current value and two lags) are all positive, but the correlation with current value is strongest so only this variable was included in the regression.

Five-year (1980–85) deforestation rates in the full sample range from −4 percent to 29 percent, with a mean of 5.5 percent; in the low and middle income sample the range is −2 percent to 29 percent and the mean is 6 percent. The coefficients can be interpreted against this background. The presence of guerrilla warfare in all years of the 1980–85 period would give that variable a value of one. The presence of guerrilla warfare at this intensity thus is associated with a 7 percent higher deforestation rate for the period when the full sample is used. (Seven percent deforestation during 1980–85 implies a compound annual rate of

1.4 percent.) The presence of revolutionary activity is associated with 1980–85 deforestation rates that are 6.8 to 10.5 percent higher than countries without revolutions. Thus, the absolute magnitudes involved are large, at least for these two variables. Likewise, five-year deforestation rates tend to be about 4 percent higher in military regimes and 3 percent lower in parliamentary democracies than in the rest of the sample.

The intuitive idea underlying this analysis is that political turmoil and repressive governments are harmful to investment. One can therefore look for corroborating evidence by examining data for ordinary investment to see if investment rates are associated with the same variables that are related to deforestation. This was done using data from Summers and Heston (1991) on investment as a share of gross domestic product, averaged for 1980 and 1985. Simple correlation coefficients between this investment measure and all of the political variables shown in Tables 4 and 5 were calculated. Briefly, the signs of all but 3 of these 17 correlations were as expected and the strongest associations were between investment and: guerrilla warfare ($\rho = -.27$), revolutions ($\rho = -.42$), constitutional changes ($\rho = -.19$), military executives ($\rho = -.25$), and "executive is a premier" ($\rho = .30$). These results were largely upheld when high income countries were excluded from the sample.[15] Summarizing, the political variables associated with deforestation tend also to be negatively associated with ordinary investment.

VI. A PRELIMINARY SYNTHESIS

The preceding results are broadly consistent with the hypotheses that deforestation results both from population growth—and the increased competition for land and natural resources that accompany it—and from political environments that are not conducive to investment. There are surely other factors that are important in determining forest cover. Conditions of climate and environment as well as cultural factors are obvious candidates, but the first-differencing procedure and use of deforestation rates rather than forest cover levels in empirical work should reduce or eliminate the damage done by omitting them.

Other possibilities are prices for goods that are complements or substitutes to forest capital, such as timber prices, prices of agricultural crops, and prices of energy sources that are substitutes for fuel wood. Observers of deforestation also have noted the importance of access costs and transportation infrastructure since these factors determine the ease of migration from cities to forests. To include these factors in the framework used here would require data that are not presently available in published sources, however. In particular, country-specific data for at least two specific years, 1980 and 1985, would be needed for measures of transportation infrastructure, timber prices, crop prices, and so forth.

Lacking such information, the political factors identified as correlates of deforestation were combined with population growth rates in a single regression equation for deforestation. In addition, a variable was formed from the investment series described above. Deforestation is a form of disinvestment, so variables such as interest rates, tax policy, and regulatory practice should influence both in similar ways. Since data on these factors are not readily available, a variable was formed as the residual from a regression equation of the investment rate on political variables found important in explaining deforestation. This residual is intended to capture aspects of the investment climate not reflected in available political attributes.

Regression results are reported in Table 7. The sign patterns exhibited earlier are largely unchanged. The elasticity of deforestation with respect to lagged population change is reduced noticeably from the level shown in Table 2 (.23–.28), however, and its significance is reduced. As before, the association between deforestation and pop-

[15] Other political variables showing strong correlations with investment rates are the frequency of coups d'état and the presence of an elected legislature.

TABLE 7
DEFORESTATION, POPULATION GROWTH, AND POLITICAL ATTRIBUTES
(OLS REGRESSION COEFFICIENTS)

Sample	All Countries		Low and Middle Income	
Population growth, 1975–80	.1744	.1860	.0704	.1247
	(1.84)	(2.21)	(0.60)	(1.27)
Guerrilla warfare, 1980–85	.0539	.0462	.0451	.0392
	(1.75)	(1.66)	(1.34)	(1.32)
Guerrilla warfare, 1975–79	−.0297	−.0156	−.0141	−.0024
	(1.00)	(0.63)	(0.43)	(0.08)
Revolutions, 1980–85	.0313	.0606	.0415	.0662
	(0.95)	(2.10)	(1.16)	(2.19)
Revolutions, 1975–79	−.0536	−.0597	−.0579	−.0636
	(−2.00)	(−2.38)	(1.92)	(2.34)
Constitutional changes, 1980–85	.0200	—	.0122	—
	(0.32)		(0.18)	
Constitutional changes, 1975–79	−.0339	—	−.0357	—
	(0.81)		(0.79)	
Military executive, 1980–85	.0220	—	.0192	—
	(0.66)		(0.55)	
Military executive, 1975–79	.0017	—	.0029	—
	(0.06)		(0.10)	
Executive is not a premier, 1980–85	.0177	.0168	.0227	.0207
	(1.25)	(1.29)	(1.42)	(1.43)
Investment residual	.0154	—	.0200	—
	(0.21)		(0.25)	
N	106	118	86	98
R^2	.21	.20	.19	.19

Note: Absolute values of *t*-statistics in parentheses.

ulation growth is stronger in the full sample than in the sample that omits high income countries. Guerrilla warfare and revolutionary activity are correlated with one another, so including both in the same equation causes the coefficients of both to decline somewhat.[16] For each measure, the coefficients for 1980–85 and 1975–80 are of opposite sign and similar magnitude, which suggests that deforestation is responsive to changes in these variables. With other variables in the model the frequency of constitutional changes and the presence of a military head of government becomes insignificant, though their signs are as expected. Again, the variable "executive is a premier" was included for 1980–85 only since its values in different time periods are highly correlated. The investment residual, included to capture unmeasured effects on investment incentives, is (perversely) positive but insignificant. It is unavailable for 12 countries so its inclusion alters the sample substantially. Figures in the second and fourth columns present estimates obtained by excluding political and other measures that lacked significance in the original regressions.

VII. CONCLUSIONS

The intent of this paper was to present descriptive statistical results and simple hypothesis tests on alternative causes of deforestation, particularly insecure ownership. Consistent associations were found between deforestation and political variables reflecting insecure ownership, and this is encouraging. The explanatory power of the model is fairly low, however, so firm conclusions would be premature. One likely reason for low explanatory power is

[16] Simple correlation coefficients range from .47 to .72.

the exclusion of relevant variables that presently are unavailable, hence an obvious task for continuing research is to obtain and examine additional data. At a basic level, the task of developing analytic models that better illuminate the fundamental causes of deforestation remains. Any such model must recognize that many, possibly most, of the factors taken as causes in popular accounts of deforestation are really determined endogenously. For example, the cost of gaining access to the forest depends on the extent of transportation infrastructure, which in turn depends on the political and regulatory climate for private investment in a country and on factors that determine the country's public investment policies. Others have mentioned high external debt as a cause of deforestation, and indeed a correlation between debt and deforestation does seem to exist. The rationale for this claim is that liquidating natural capital is one way for a country to meet financial obligations. Yet high debt and high deforestation may both be caused by a third force. The results reported earlier, plus the casual observation that the most indebted countries are often those in greatest political turmoil, suggest one interesting possibility.

Yet the political indicators of insecure property rights examined here probably should not be regarded as truly exogenous either. Political unrest and the instability or repression it can cause may result from inequality of wealth, from rapid population growth and the consequent dilution of land and other natural resources in a country, from cultural or religious factors, or other forces. Unraveling this chain of causation is centrally important to any policy intended to control deforestation or the use of other natural resources. Absent an understanding of these causes, and a firm basis for separating causation from correlation, policy in this arena will mistakenly treat symptoms rather than causes.

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