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Governance and Timber Harvests

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Abstract Resource economics theory implies that risks associated with weak governance have an ambiguous impact on extraction, with the net impact depending on the relative strengths of depletion and investment effects. Previous empirical studies have found that improved governance tends to reduce deforestation but to raise oil production. Here, we present evidence that the marginal impact of improved governance on timber harvests in developing countries during 1984–2006 was nonmonotonic. It tended to raise harvests in countries with weaker governance but to reduce harvests in countries with stronger governance. This nonmonotonic impact occurred for both an index of governmental integrity (corruption, bureaucracy quality, law and order) and an index of governmental stability. A simulation of hypothetical increases in these governance indices to the maximum 2006 values observed in the sample predicted that improved governance would reduce harvests in most countries but could raise harvests in some, with large increases occurring in countries with the weakest governance.

Keywords Forests · Timber · Governance · Corruption · Developing countries

1 Introduction

This paper presents an empirical investigation into the impact of governance on commercial timber harvests in developing countries. The direction of the impact—positive, negative, or nonmonotonic—is not clear from the existing literature. Consider, for example, an aspect of governance that has attracted substantial recent attention within the international forest

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policy community: corruption. Surprisingly few empirical studies have examined the impact of corruption on the extraction of commercial natural resources, despite concern about the influence of corruption on the allocation of resource extraction rights (Collier and Hoeffler 2004, pp. 3, 12–14; Rose-Ackerman 2004, pp. 34–37). The conventional wisdom appears to be that corruption accelerates timber harvests. For example, the World Bank (2004, p. A-13) has stated that "Many countries with substantial forest resources have been subject to corruption … resulting in a short-term, wasteful, and inefficient approach to forests and their use by the vested interests that have gained control over these resources."

In contrast, the literature on corruption and investment implies that corruption might instead reduce the extraction rate for natural resources. Starting with Mauro (1995), a series of empirical studies have presented evidence that corruption depresses investment at a macroeconomic level.[1] One might expect resource extraction to be among the sectors most affected, as it tends to be more capital-intensive than most. Resource extraction involves investments in specialized infrastructure (port facilities, pipelines, logging roads), structures (oil platforms, mine shafts, logging camps), and heavy machinery (earthmoving equipment and loaders in the case of mining, skidders and log trucks in the case of logging). Consistent with this expectation, Bohn and Deacon (2000) found that petroleum extraction is lower in countries where investment risk is higher. They did not include corruption in their measure of investment risk, but investors certainly do view corruption as a significant source of risk.[2] Although commercial logging is not as capital-intensive as petroleum extraction or mining, scattered available information indicates that fixed costs account for a third to more than half of total logging costs in developing countries (Page et al. 1976, Table 7, for Ghana; Ruzicka 1979, Table 1, for Indonesia; Vincent 1990, Appendix, for Malaysia; Stone 1998, Table 5, for Brazil).

If corruption effectively adds a risk premium to investors' discount rates, then we know from the analysis by Farzin (1984) of resource extraction in the presence of capital costs that the impact on the extraction rate is theoretically ambiguous. On the one hand, a higher discount rate tends to tilt the extraction profile toward the present, by reducing the value of future resource rents relative to current ones. This depletion effect is a familiar feature of both nonrenewable and renewable resource models (Dasgupta and Heal 1979; Dasgupta 1982).[3] On the other hand, by reducing the present value of the resource stock, a higher discount rate reduces the incentive for investors to provide the capital that extraction requires, and for that reason it tends to slow extraction. The net impact depends on the relative strength of the two effects. Hence, both the conventional wisdom about the impact of corruption on timber harvests and the opposite view implied by the corruption literature can be explained by resource economics theory. The impact of corruption on investment risk does not preclude corruption from affecting resource extraction in other ways, but it is sufficient for demonstrating that corruption's effect is theoretically ambiguous.

Corruption is just one aspect of governance. Another is stability. Governmental instability would appear to be even more directly linked to investment risk than corruption is. Farzin's findings thus imply that it too could have either a positive or a negative impact on timber harvests. Corruption and instability might also interact. Case studies on the Philippines and Indonesia indicate that timber was extracted at rates exceeding sustained yield only during

[1] Bardhan (1997, pp. 1327–1329), Jain (2001, pp. 93–97), and Rose-Ackerman (2004, pp. 4–9) review this literature.

[2] Indeed, private firms that analyze country risks for investors are a common source of cross-country data on corruption (Johnston 2001; Kaufmann et al. 1999b).

[3] Farzin referred to this as a "conservation effect," as he framed the discussion in terms of risk reductions.

periods when Presidents Marcos and Suharto, widely considered to be icons of corruption, were not firmly in power (Ross 2001, p. 194). Similarly, in the first formal resource-extraction model linked to electoral politics, Robinson et al. (2006) demonstrated that electoral uncertainty causes self-interested politicians to extract resources at a rate above the social optimum.

We investigated the impact of governance on commercial timber harvests by analyzing panel data on developing countries during 1984–2006. We analyzed two sets of countries. One included all 90 countries for which data were available on both harvests and governance; the other included the 67 countries for which data were also available on neoclassical factors affecting harvests. We focused on developing countries because state ownership of forests is more pervasive there than in developed countries (FAO 2007, Figure 77), which implies greater government control over the harvest rate. We used data from the International Country Risk Guide produced by Political Risk Services (PRS) to construct two composite indices of governance. One included indicators of corruption and other aspects of governmental integrity, while the other included indicators of governmental stability.

To our knowledge, our study provides the first cross-country econometric evidence on the impact of governance on commercial timber harvests. Barbier et al. (2005) examined the impact of corruption on deforestation, finding that deforestation is more rapid in more corrupt countries, but there is reason to believe that the impact of corruption and other aspects of governance could be different for timber harvests. Agricultural conversion, not commercial logging, is the major cause of deforestation in developing countries (Chomitz 2007). A meta-analysis by Geist and Lambin (2001) found that logging led directly to deforestation in only five of the 152 cases they reviewed, although logging likely facilitated farmers' access to forestland in some of the others. Bohn and Deacon (2000) included deforestation in their study on ownership risk and resource use as a case that contrasted with petroleum, arguing that most deforestation is not very capital-intensive. Consistent with this difference, they found that deforestation is higher when investment risk is higher, the opposite of their finding for petroleum extraction. Although commercial logging is less capital-intensive than petroleum extraction, it is more capital-intensive than deforestation, at least when the latter is driven by smallholder land-clearing. The impact of governance on logging might therefore differ from the impact on deforestation.

We found that it does. Marginal improvements in governance tend to increase harvests in countries where governance is weaker but to decrease harvests in countries where it is stronger. This nonmonotonic relationship holds for both governance indices in both sets of countries and is robust to various changes in model specification. It suggests that the investment effect dominates the depletion effect when the level of governance is low, with the reverse being true when the level is high. The impact of governance on commercial timber harvests (nonmonotonic) thus differs from previously reported estimates of the impact on deforestation (monotonic according to both Bohn and Deacon 2000; Barbier et al. 2005).

We used our econometric results to predict the impacts of large, hypothetical improvements in governance on 2006 harvests in the larger timber-producing countries, with the improvements defined as the governance indices rising to the maximum observed values among those countries. We predicted that harvests would fall in around two-thirds of the countries. For a few countries with very low levels of governance, however, harvests would actually rise. Our results therefore indicate that the conventional wisdom holds for most countries—improvements in governance reduce harvests—but, in a few countries, programs to improve governance could affect timber harvests in a way opposite to what their proponents intend.

2 Methods

2.1 Overview

We defined "developing countries" as countries that were not members of the OECD as of 1984, which is the initial year for the PRS governance data. Our strategy for identifying the impact of governance on commercial timber harvests involved the estimation of a sequence of three models. All had a logarithmic transformation of harvest as the dependent variable ($\ln(q_{it})$; i = country, t = year), which was partially explained by a nonlinear function of the governance indices ($f(I_{it}, S_{it})$; I_{it} = integrity, S_{it} = stability). The sample period ended with 2006, which is the most recent year with reasonably complete cross-country data on both harvests and governance.

The simplest model was a pooled OLS model,

$$\ln(q_{it}) = \mu + f(I_{it}, S_{it}) + \varepsilon_{it}, \quad (1)$$

where μ is the intercept and ε is the error term. This model provides a natural starting point, as it ignores the impacts of all other variables that affect harvests (e.g., prices). It uses variation both within and between countries to identify the impact of governance. It provides unbiased estimates of the impact, however, only if the governance indices are uncorrelated with the omitted variables. Even then, the omission of those variables reduces the efficiency of the estimates, thus increasing the probability of Type II error. A positive feature of this model is that it yields the largest sample size—90 countries and 1,660 observations (see Appendix Table 8 for a country list)—as no observations are dropped due to missing data on the omitted variables.

The second model was a fixed-effects (FE) version of (1),

$$\ln(q_{it}) = \mu_i + f(I_{it}, S_{it}) + \nu_{it}, \quad (2)$$

where the intercept varied by country. Assuming that the intercept does indeed vary by country, which is a testable hypothesis, this model reduces omitted variable bias (the fixed effects fully capture the impacts of all time-invariant, country-specific variables)[4] and increases efficiency (by explaining more of the variation in harvests across countries) without reducing the sample size. It uses only temporal variation within countries to identify the impact of governance, however. A random-effects model would not be appropriate, because the 90 countries include virtually all timber-producing developing countries and thus represent essentially the entire population, not a random sample drawn from it (Mundlak 1978, p. 70; Kennedy 1992, p. 222).

A concern sometimes raised with FE models is that the within-country variation in governance variables is too small to reveal significant impacts even when such impacts actually exist. This is an empirical issue, in two senses. First, one can examine the relative amounts of within and between variation in governance variables and determine how large the former is compared to the latter. Second, if governance variables are found to have a significant impact despite the elimination of between-country variation by the fixed effects, then one can be especially confident that a significant impact exists. The reverse is not true, however: if governance variables do not have a significant impact, then one cannot be sure if the lack of significance is an economic result (governance truly does not affect harvests) or

[4] The fixed effects also control for persistent cross-country differences in forest ownership shares (public, private, community). Cross-country data on forest ownership are surprisingly scarce. FAO recently launched a project to rectify this (www.fao.org/forestry/tenure/en).

a purely statistical one (the variables do not have enough within-country variation to reveal their impacts).

The final model added neoclassical variables (**X**) to (2):

$$\ln(q_{it}) = \mu_i + f(I_{it}, S_{it}) + \mathbf{X}\boldsymbol{\beta} + \varphi_{it}. \quad (3)$$

Econometric estimation of timber supply functions dates from the 1960s (McKillop 1967), and the basic theory is well-established (Binkley 1987). In a standard specification, **X** includes the price of harvested timber, the prices of variable inputs such as labor and fuel, the logging industry's discount rate, the standing stock of timber in the forest, and quantities of fixed inputs such as logging roads and logging machinery. The inclusion of the discount rate and timber stock distinguishes timber supply functions from conventional short-run supply functions for static production processes. All the neoclassical variables are expected to have positive impacts on harvests except input prices. The addition of the neoclassical variables should reduce omitted variables bias (if the variables are in fact correlated with the governance indices) and increase efficiency. A negative feature is that the sample shrinks to 67 countries and 930 observations (see Appendix Table 8), as data on neoclassical variables are not available for all countries in all years.

We estimated variations on these basic models to explore the nonlinear form of $f(I_{it}, S_{it})$. Our objective was to determine whether governance has a statistically significant impact on timber harvests and to determine the nature of that impact: positive, negative, or nonmonotonic. We paid particular attention to the similarity of coefficient estimates in $f(I_{it}, S_{it})$ across the three models, which provides evidence on robustness. We also considered the consistency of the coefficient estimates on the neoclassical variables with forest economics theory, which provides evidence on the economic plausibility of (3).

2.2 Governance Indices

Cross-country data on governance in the forest sector do not exist, although surveys in particular countries are starting to be conducted (e.g., Smith et al. 2003 for Indonesia; Zinnes et al. 2007 for Romania). The economywide PRS indicators that we used are the most popular governance indicators used in cross-country studies (Knack 2002, p. 10). They offer broad country coverage, which reduces the risk of selection bias (Kaufmann et al. 1999a; Johnston 2001), and they are available for a relatively long time period (1984 to the present), which is an important advantage for FE models.[5]

The dataset that PRS makes available to academic researchers includes five governance indicators:[6] Corruption, Bureaucracy Quality, Law and Order, Government Stability, and Democratic Accountability.[7] (See Appendix Table 9 for definitions.) The indicators are ratings, with higher values indicating better governance, even in the case of the Corruption indicator. We constructed the integrity index as a composite of the first three indicators, which previous research has found are closely related (Mauro 1995; Jain 2001;

[5] In contrast, the World Bank's Worldwide Governance Indicators (WGI; Kaufmann et al. 2009) are available for only 8 out of the 23 years covered by our analysis. Morever, the years are clustered during the second half of the period (1996, 1998, 2000, 2002–2006), which reduces the amount of within-country variation in the indicators.

[6] www.prsgroup.com/AcademicTitles.aspx.

[7] It also contains other country risk indicators, including measures of internal and external conflict, ethnic tension, and roles of the military and religion in government.

Johnston 2001; Lambsdorff 2003; Rose-Ackerman 2004). [8] We converted each to a 0–1 scale and then averaged them.[9] 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 (Knack and Keefer 1995; Mauro 1995, 1997; Knack 2002). We constructed the stability index similarly, by averaging the two remaining indicators.[10] Because the indices can equal zero, we did not express them as logarithms.

We explored the nonlinearity of the impacts of the governance indices by including interactions between the two indices and by using three different specifications of $f(I_{it}, S_{it})$: a quadratic specification, a piecewise linear spline transformation, and a dummy variable specification. We allowed for interactions between the two indices in all three. In the linear spline model, we transformed each index into two equal-width groups. In the dummy variable model, we recoded each as a set of five dummy variables, with Dummy 1 referring to values between 0 and 0.2, Dummy 2 referring to values between 0.2 and 0.4, etc. We excluded the Dummy 1 variables to avoid singularity, and so the coefficients on the other dummies indicate impacts relative to governments with the least integrity or stability.

There is some rough evidence that economywide governance indicators are decent proxies for governance in the forest sector. The World Bank conducted a firm-level World Business Environment Survey in 1999.[11] The survey included two corruption-related questions, which slightly paraphrased were "How common is it for firms in your line of business to have to pay some irregular 'additional payments' to get things done?" and "Do firms like yours typically need to make extra, unofficial payments to public officials to gain government contracts?" Mean responses were reported by sector. Although there was not a separate logging sector, there was a broader sector that included it, "Agriculture, hunting, fishing, and forestry." The survey included sixteen of the countries in our sample. For each country, we tested whether mean responses in the "Agriculture, hunting, fishing, and forestry" sector differed from mean responses across all sectors. We found that they did not differ significantly in any of the sixteen countries for the first question and differed in only two for the second. If, despite this favorable evidence, the economywide governance indicators that we used are not good proxies for governance in the forest sector, then our estimates of the impact of governance on timber harvests are biased toward zero, which makes them conservative estimates.

[8] Our PRS-based integrity index can be compared to a corresponding index based on the WGI for the 8 years when data are available for both (see footnote 5). We constructed the latter by taking the average of four of the six variables in the WGI: Control of Corruption, Rule of Law, Regulatory Quality, and Government Effectiveness. The correlation coefficient for the two indices was 0.80, which indicates that they provide quite similar measures of governmental integrity.

[9] Following Humphreys and Bates(2005; see also Knack and Keefer 1995, p. 212), we also constructed a composite variable by taking the first principal component of the three indicators. Regression results differed little when we used this variable instead of the mean. We also considered applying the aggregation methodology developed by Kaufmann et al. (1999a), but as one of the authors (Aart Kraay) pointed out to us, applying it to data from a single, relatively complete source such as PRS is essentially equivalent to using the first principal component.

[10] PRS views its Democratic Accountability indicator as being related to governmental stability (see Appendix Table 9). As with the integrity index (see footnote 8), our stability index can be compared to a corresponding index based on the WGI. We constructed the latter by taking the average of the two remaining WGI variables: Voice and Accountability, and Political Stability and Absence of Violence/Terrorism. The correlation coefficient for the two indices was 0.65. We also found that our stability index is significantly and negatively correlated with regime changes (or transition periods defined by the lack of stable political institutions) implied by the Durable variable in the Polity IV database (www.systemicpeace.org/polity/polity4.htm). We thank a reviewer for suggesting that we investigate these other sources of cross-country governance data.

[11] www.ifc.org/ifcext/economics.nsf/Content/ic-wbes.

There is in fact an econometric advantage to using economywide indicators instead of ones specific to the forest sector: economywide indicators are less likely to be simultaneously determined with timber harvests. Endogeneity of governance variables has been a recurrent concern in cross-country studies (Mauro 1995, 1997; Knack 2002).[12] The logging sector is such a small component of most countries' economies, however, typically less than a percentage point, that timber harvests surely have a negligible impact on economywide governance indicators.

2.3 Forestry Variables

We obtained data on commercial timber harvests (total production, not just harvest intended for export) from the U.N. Food and Agriculture Organization's (FAO) cross-country forest products database, ForesSTAT.[13] We selected the industrial roundwood series, which is measured in cubic meters and is the broadest measure of wood used for commercial purposes (sawlogs, veneerlogs, pulpwood). We deleted "placeholder" values: FAO substitutes values from year t if countries do not report values for years $t + 1$ to $t + n$. This is an important data-cleaning procedure, and it affects many years of data for some countries. We set the price of harvested timber (i.e., industrial roundwood) equal to export unit value,[14] also from ForesSTAT and measured in U.S. dollars per cubic meter. We converted the unit values to real terms by using each country's dollar-denominated GDP deflator (base year = 2000) from the World Bank's World Development Indicators (WDI) database. For countries with few or no exports in particular years, we filled in missing values using export unit values averaged across other countries in the same region as defined by FAO (2007). To cross-check this procedure, we also estimated (3) without these observations.

Cross-country data on discount rates and input prices specific to the logging industry do not exist. For the industry's discount rate, we used each country's real lending rate from the WDI. For fuel price, we used country-specific pump prices of the most widely sold grade of diesel, which is the fuel used in most logging machinery. The WDI reports these data for selected years (1991, 1993, 1995, 1998, 2000, 2002, 2004, 2006). We converted these prices to constant 2000 U.S. dollars, and we imputed values for remaining years by using predicted values from a fixed-effects model in which we regressed the logarithm of diesel price on the logarithm of the world spot price for oil and the GDP deflator (see Appendix Table 10). As a proxy for logging wage, we used WDI data on agricultural value added per worker, reported in constant 2000 U.S. dollars. Agriculture is the major source of alternative employment in rural regions where logging occurs, and so agricultural wages should provide a good estimate of the opportunity cost of labor. Cross-country data on agricultural wages

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[12] See Bulte and Damania (2008) for a recent review of the literature on the influence of natural resource endowments on corruption, and Alexeev and Conrad (2009) for evidence that resource endowments do not affect governance in the case of oil.

[13] faostat.fao.org/site/626/default.aspx#ancor

[14] We used export unit values because cross-country data on domestic roundwood prices are not regularly compiled by FAO or any other organization. We mimicked global forest-sector models by assuming that the law of one price prevails in the global marketplace, with roundwood export prices varying across countries due to differences in transportation costs and trade taxes. Although we used export prices in the harvest model, the estimated coefficient on the price variable would have been the same if we had instead used domestic prices, as long as any discrepancy between export and domestic prices was due to exogenous factors (e.g., transportation costs and trade taxes) and was constant over time in percentage terms within a given country. This is because we included the neoclassical variables in logarithmic form in a FE model. If export price is a poor proxy for domestic price, however, then the roundwood price variable in our model suffers from measurement error, and the estimated coefficient on it is biased toward zero.

do not exist,[15] however, so we followed agricultural economists in using agricultural value added per worker as a proxy for it (e.g., Timmer and Akkus 2008).[16] Given that we in effect used a proxy for a proxy, we also estimated (3) without this variable.

We chose not to include timber stock as a single variable but rather to include the two variables whose product it equals, forest area and timber density (timber stock per unit area), as separate regressors. This more flexible specification potentially controls for some unobserved factors that affect logging costs. For example, logging costs tend to be higher when timber density is lower, as harvestable trees are more scattered. We obtained data on total forest area, measured in thousand hectares and encompassing both natural forests and plantations, for 1990, 2000, and 2005 from FAO (2001a, 2005, 2007). We interpolated estimates for other years by calibrating an exponential curve to the three observations for each country. We obtained data on timber density, defined as "total volume over bark of living trees above 10 cm diameter at breast height" and measured in cubic meters per hectare, for the same three years from FAO (1995, 2001b, 2007). We interpolated the estimates for other years using the same method as for forest area.

We were unable to identify a source of data on fixed inputs used by the logging industry or proxies for such inputs. It is not clear, however, that any bias stemming from the omission of variables for fixed inputs is of concern for our analysis. As discussed in Sect. 1, investment in fixed inputs is one of the primary mechanisms through which governance is expected to affect resource extraction. The omission of fixed inputs thus causes regression coefficients on the governance indices to reflect more fully the impacts of governance on harvests: they reflect longer-run impacts, not just short-run impacts conditional on current stocks of fixed inputs. Put another way, if we included variables for fixed inputs, then the coefficients on the governance variables would reflect primarily the impact of the depletion effect. We are interested in the net impact of both the depletion and investment effects.

We expressed all neoclassical variables in logarithmic form except the real lending rate, which was negative for some countries in some years. We lagged forest area and timber density to ensure they were not endogenously determined with timber harvests, which *ceteris paribus* reduce timber stocks (= forest area × timber density).[17]

2.4 Summary Statistics

Table 1 shows summary statistics for the smaller (67-country) sample. There was substantial variation in timber harvests and the neoclassical timber-supply variables, with standard deviations being comparable to or greater than means.[18] The governance indices varied less, with

[15] David Dawe, FAO, personal communication, March 31, 2009; C. Peter Timmer, Center for Global Development, personal communication, March 31, 2009. The International Labour Organisation reports wage data only for nonagricultural sectors.

[16] We note that agricultural value added per worker does not need to equal the unobserved logging wage. It just needs to change from year to year in a similar percentage way. See footnote 14.

[17] Endogeneity is not a significant concern for industrial roundwood price. The global forest sector is highly competitive, with many exporters and importers, much substitution between different types of timber, and no developing country exerting substantial market power.

[18] The ratio of maximum to minimum values is extremely high for the three prices in the model (industrial roundwood, diesel, agricultural value added per worker). This results from unusually high or low values for a small number of countries. For example, diesel price is very low in some oil-producing countries in the sample. Coefficient estimates on the governance variables were not very sensitive to the inclusion or exclusion of these countries.

Table 1 Summary statistics

Variable	Mean	Std. Dev.	Min	Max
Integrity (0–1)	0.467	0.158	0.056	0.847
Stability (0–1)	0.580	0.160	0.229	0.951
Industrial roundwood production (‘000 m^3)	7,282	18,900	3.3	121,000
Forest area (‘000 ha)	27,935	56,829	226	503,769
Timber density (m^3/ha)	99.1	61.4	13.1	348.5
Industrial roundwood price (2000 US\$/m^3)	0.162	0.138	0.016	1.583
Diesel pump price (2000 US\$/l)	0.373	0.143	0.018	1.149
Agricultural value added per worker (2000 US\$)	2,126	5,351	61	76,177
Real interest rate (decimal)	0.076	0.180	-0.981	1.330

N (number of observations) = 930
n (number of countries) = 67 (see Appendix Table 8)
Sample period: 1984–2006

Table 2 Decomposition of standard deviation of governance variables

Variable	Overall	Between groups	Within groups
Integrity	0.158	0.127	0.099
Stability	0.160	0.118	0.121

N = 930
n = 67
Sample period: 1984–2006

standard deviations being on the order of a third of the means or smaller. This is partly a consequence of the indices being bounded by 0 and 1: if the means equaled 0.5, which they nearly do, then the standard deviations could be no larger. Standard deviations were larger for all the variables in the larger (90-country) sample.

Table 2 decomposes the standard deviations of the governance indices into their within-country and between-country components, again for the smaller sample. Although the within-country standard deviations are smaller than the overall ones, the within-country component is not much smaller than the between-country component for *Integrity* and is actually larger for *Stability*. A substantial portion of the variation in the governance indices thus remains even when fixed effects are added, as in (2) and (3). Moreover, although the two indices are positively correlated, they are only moderately so ($r = 0.53$ in both samples). A regression model might thus be able to distinguish the impacts of the two.

3 Results

3.1 Estimation of Models (1)–(3)

Tables 3, 4, and 5 present estimation results for various specifications of (1), (2), and (3). All standard errors were computed using the Newey-West estimator, which corrects for heteroskedasticity. The Newey-West standard errors did not differ much from the uncorrected ones.

Table 3 Regression results: models (1) and (2)

	Model (1): OLS			Model (2): FE		
Variable	Linear	Quadratic	Quadratic with interaction	Linear	Quadratic	Quadratic with interaction
Integrity	0.86** (0.36)	2.11 (1.43)	2.26 (1.51)	0.21** (0.097)	1.46*** (0.36)	1.29*** (0.39)
Integrity^2		−1.58 (1.47)	−1.19 (1.95)		−1.44*** (0.38)	−1.97*** (0.45)
Stability	0.97*** (0.35)	5.08*** (1.72)	5.03*** (1.73)	0.012 (0.096)	0.91** (0.45)	0.99** (0.44)
Stability^2		−3.79** (1.49)	−3.37* (2.04)		−0.85** (0.39)	−1.40** (0.51)
Integrity × stability			−0.92 (3.03)			1.20 (0.73)
Constant	12.8*** (0.18)	11.5*** (0.41)	11.5*** (0.41)			
Turning points						
• Integrity		0.67	0.95[a]		0.51	0.33[a]
• Stability		0.67	0.75[a]		0.54	0.36[a]
Elasticities @ 0.25						
• Integrity		0.33	0.41[a]		0.19	0.08[a]
• Stability		0.80	0.84[a]		0.12	0.07[a]
Elasticities @ 0.75						
• Integrity		−0.19	0.35[a]		−0.52	−1.24[a]
• Stability		−0.45	−0.02[a]		−0.27	−0.83[a]
N	1660	1660	1660	1660	1660	1660
n	90	90	90	90	90	90
R^{2b}	0.02	0.02	0.02	0.004	0.02	0.02

Dependent variable natural logarithm of industrial roundwood production.
Two-tailed test: *** significant at 0.01, ** at 0.05, * at 0.1. Newey-West standard errors in parentheses.
Sample period: 1984–2006.
[a] Calculated without the interaction term.
[b] Adjusted R^2 in model (1), within R^2 in model (2)

Table 4 Regression results: FE estimates of quadratic specification of model (3)

Variable	All variables and observations	Exclude agricultural VA/worker	Exclude regional roundwood prices	Only larger timber-producing countries
Integrity	1.11** (0.44)	2.11*** (0.46)	1.21** (0.56)	1.71*** (0.48)
Integrity^2	−0.96** (0.44)	−2.06*** (0.48)	−0.87 (0.57)	−1.75*** (0.44)
Stability	2.09*** (0.70)	1.48* (0.77)	1.88** (0.91)	1.88** (0.73)
Stability^2	−1.72*** (0.59)	−1.28** (0.63)	−1.69** (0.77)	−1.28** (0.57)
Forest area	0.70*** (0.25)	0.80*** (0.25)	0.84*** (0.23)	1.56*** (0.21)
Timber density	0.13*** (0.047)	0.11** (0.047)	−0.062 (0.057)	0.084** (0.040)
Roundwood price	0.051** (0.022)	0.074*** (0.022)	0.024 (0.029)	0.037 (0.023)
Diesel price	−0.19** (0.097)	−0.16 (0.10)	−0.014 (0.13)	−0.12 (0.092)
Agricultural VA/worker	$5.4 \times 10^{-5*}$ (3.2×10^{-5})	–	$6.5 \times 10^{-5*}$ (3.5×10^{-5})	$12 \times 10^{-5***}$ (1.9×10^{-5})
Interest rate	0.38*** (0.098)	0.26*** (0.085)	0.31** (0.12)	0.13 (0.14)
Turning points				
• Integrity	0.58	0.51	0.70	0.49
• Stability	0.61	0.57	0.56	0.73
Elasticities @ 0.25				
• Integrity	0.16	0.27	0.19	0.21
• Stability	0.31	0.21	0.26	0.31
Elasticities @ 0.75				
• Integrity	−0.24	−0.74	−0.07	−0.69
• Stability	−0.37	−0.34	−0.49	−0.03
N	930	1067	667	487
n	67	76	59	33
R^2(within)	0.12	0.09	0.08	0.29

See notes for Table 3.
All explanatory variables except the interest rate and the governance variables are also in logarithms.

Table 5 Regression results: FE estimates of flexible specifications of model (3)

Variable	Linear spline	Dummy variable
Forest area	0.65** (0.25)	0.78*** (0.24)
Timber density	0.12** (0.048)	0.14*** (0.046)
Roundwood price	0.054** (0.023)	0.057** (0.023)
Diesel price	−0.19* (0.098)	−0.21** (0.098)
Agricultural VA/worker	$5.3 \times 10^{-5*}$ (3.1×10^{-5})	$5.4 \times 10^{-5*}$ (3.1×10^{-5})
Interest rate	0.39*** (0.099)	0.38*** (0.098)
Spline 1: Integrity	0.60*** (0.23)	–
Spline 2: Integrity	−0.051 (0.21)	–
Spline 1: Stability	0.53 (0.33)	–
Spline 2: Stability	−0.16 (0.21)	–
Dummy 2: Integrity	–	0.24*** (0.069)
Dummy 3: Integrity	–	0.28*** (0.072)
Dummy 4: Integrity	–	0.24*** (0.084)
Dummy 5: Integrity	–	0.089 (0.093)
Dummy 2: Stability		0.032 (0.094)
Dummy 3: Stability		0.053 (0.074)
Dummy 4: Stability		0.11* (0.062)
Dummy 5: Stability		–[a]
N	930	930
n	67	67
R^2 (within)	0.11	0.13

See notes for Table 3

[a] The stability index did not exceed 0.8 for any observations in this sample

Table 3 presents results for (1) and (2), which include only the governance indices. The FE estimates for (2) are qualitatively similar to the OLS estimates for (1).[19] Coefficients are positive on both indices in the linear specifications, which implies that stronger governance is associated with higher harvests (although the FE estimate on *Stability* is not significantly different from zero at $P \leq 0.05$). The impact of both indices is revealed to be nonmonotonic, however, when quadratic terms are added: the estimate remains positive on the linear term but is negative on the quadratic term. Improvements in governance are thus evidently associated with increased harvests when the indices are at lower levels but decreased harvests when they are at higher levels. This pattern suggests that the investment effect dominates when governance is weaker, while the depletion effect dominates when governance is stronger.

Evidence of a nonmonotonic relationship is strongest for the FE estimates, which are significant for the linear and quadratic terms of both indices. This results from the increased efficiency (much smaller standard errors) of the FE estimates. The FE estimates are preferred for this reason and also because F tests rejected the equality of fixed effects across the countries. The interaction term between the indices is not significant in either model, and so a purely quadratic model captures the impact of governance best. The two indices do interact

[19] R-squareds for FE models in the tables refer to only the within-variation explained by the models. R-squareds for the overall variation are much higher. For example, they are 0.97 for the three FE models in Table 3.

indirectly, however: given that the dependent variable is logarithmic, changes in one index affect the marginal impact of the other, even without an interaction term.

In addition to reducing the standard errors, the fixed effects tend to reduce the magnitudes of the coefficients in the quadratic model, especially those on *Stability*. This could have either a purely statistical cause (the elimination of between-country variation) or an economic one (harvests are affected by time-invariant country characteristics, which, if not controlled for, inflate the magnitudes of the coefficients). The turning points in the FE quadratic model are comparable to the sample means for the governance indices across the 90 countries.[20] They thus represent true turning points, not just a diminishing of the impact of governance at higher levels. Both indices have inelastic impacts on harvests at both lower (0.25) and higher (0.75) index values in the quadratic model.

Table 4 presents FE estimates for quadratic specifications of (3), which includes the neoclassical variables. (Results for specifications with interaction terms are not shown, as the latter were insignificant.) The sign pattern for the governance variables is the same as in Table 3 across the four specifications shown: a specification that includes all available observations and all variables (column I); ones that exclude agricultural value added per worker (column II) or roundwood price estimates based on regional values (column III); and one with the sample limited to the largest timber-producing countries, defined as countries with mean production above the sample median (column IV). We included the last model to check whether the nonmonotonic relationship was driven by observations from smaller timber producers, which might make it less meaningful from a global policy standpoint. The coefficient estimates on the governance variables are significant in nearly all cases but vary somewhat due to differences in specifications and numbers of countries included (67, 76, 59, and 33, respectively). The results are quite similar despite this variation, with turning points all within the relatively narrow range of roughly 0.5–0.7 and the impacts of the indices remaining inelastic.[21]

Coefficient estimates on the neoclassical variables that are significant in Table 4 have the expected signs, with the exception of the coefficient on agricultural value added per worker (although it is significant at $P \leq 0.05$ in just one case). Given that all the variables except the interest rate are expressed in logarithmic form, the estimates can be interpreted as elasticities. The elasticity is around 1 for forest area, which is a condition sometimes imposed in timber supply models (Binkley 1987; Binkley and Dykstra 1987), and much less than 1 for roundwood price, which is consistent with previous studies (Binkley 1987).

The most robust finding in Tables 3 and 4 is the nonmonotonic relationship between timber harvests and governance.[22] Table 5 presents results from additional investigations into this

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20 The means are 0.45 for *Integrity* and 0.56 for *Stability*.

21 The similarity of the turning points and, to an extent, the elasticities in the fifth column of Table 3 and the first column of Table 4 suggests that the addition of the neoclassical variables—in particular, the price variables—does not mask much of the full general-equilibrium effects of governance. To check this more carefully, we ran a regression that was the same as the one in the first column of Table 4 except for excluding roundwood price. The coefficients on the governance variables barely changed. We also ran a regression that was the same as in the second column of Table 4—i.e., it excluded agricultural VA/worker—except that the sample was limited to the 67 countries in the first column. The coefficients on the governance variables were again virtually identical to those in the first column, thus implying that any differences between the results in the first and second columns were driven by differences between the samples (67 vs. 76 countries), not by masking of general-equilibrium effects by agricultural VA/worker.

22 Because we estimate FE models, the identification of this relationship depends critically on the amount of within-country variation in the governance indices. It is thus not surprising that the relationship is not robust to large reductions in sample length from the 23 years that we analyzed. Few coefficient estimates remain significant if we limit the sample to the 8 recent years for which data are available for both the PRS and WGI

relationship. The linear spline model yields the same sign pattern for both indices—positive on the first spline, negative on the second—but only one of the four coefficients is significant. An explanation could be that the relationship is more of an inverted U than an inverted V. If so, then the coefficients on the indices when expressed as dummy variables should be larger for the intermediate dummies than for the smallest and largest ones. That is what Table 5 shows for *Integrity*. The three intermediate dummies are all significantly larger than the excluded one (which, recall, was the smallest one), but the largest one is not; the implied turning point is in the range of 0.4–0.6, which overlaps with the ones in Table 4. Evidence is weaker for *Stability*, with the coefficient estimates indicating an increasing impact but none of them significantly different from zero at $P \leq 0.05$.

Although the nonmonotonic relationship is econometrically robust in the quadratic models and, for *Integrity*, in the more flexible models too, underreporting of timber harvests could potentially explain the lower harvests when governance is weaker. Countries with high levels of corruption are also reported to have high levels of illegal logging (World Bank 2004), and illegally harvested timber might not be included in the FAO statistics.[23] The most common method for detecting underreporting is to compare apparent consumption[24] of industrial roundwood used in the production of solid wood products (= sawnwood plus wood-based panels) to output of solid wood products. If harvests are underreported, then the observed input–output ratio (the inverse recovery rate) will be unusually low. This suggests an econometric test: regress inverse recovery rates on the governance indices and other pertinent variables, and determine whether the coefficients on the governance indices are significant and positive, which would indicate that underreporting is greater when governance is weaker.[25] We regressed the inverse recovery rates on country fixed effects (to control for cross-country differences in technology), a time trend (to control for technological change), the ratio of sawlog/veneerlog price to sawnwood price (to control for efficiency responses to price changes), and either *Integrity*, both indices, or a quadratic specification of the two indices. As results in Table 6 show, only the time trend was significant. Underreporting apparently does not explain lower harvests when governance is weaker.

Footnote 22 continued
indicators (see footnotes 5, 8, 10). This is true whether we use our PRS-based indices or corresponding ones based on the WGI. The within-group standard deviations of the WGI-based integrity and stability indices, 0.033 and 0.038 respectively, are only a third as large as the within-group standard deviations of the PRS-based integrity and stability indices for the full 1984–2006 sample, 0.099 and 0.121. The amount of within-country variation in the WGI-based indices—or the PRS-based indices when the same short sample is used—is not sufficient to identify the impacts of governance on timber harvests with much confidence.

23 Published estimates of illegal logging should not be equated to harvest underreporting, as they typically include many other types of illegal activities, such as failing to comply with logging regulations, logging in unauthorized areas (e.g., national parks), and misstating the value or species (but not necessarily the quantity) of shipments. See a 2002 special issue of the International Tropical Timber Organization's quarterly newsletter, *Tropical Forest Update* (vol. 12, no. 1), on forest crime. One highly regarded report estimates that, in the aggregate, only 13% of roundwood production in the 5 countries/regions that it investigated was from "suspicious sources," a term that encompassed all types of illegal activities, not just underreporting (Seneca Creek Associates and Wood Resources International 2004).

24 Production plus imports minus exports.

25 A reviewer pointed out that this test could be misleading if substantial volumes of unreported logs are directly exported rather than used as domestic inputs. If so, then reported global exports should be significantly less than reported global imports. To investigate this, we examined FAO data on global exports and imports of tropical logs (the category "Ind Rwd Wir (NC) Tropical") during the entire period for which data are available (1990–2006). Summed over the 17-year period, global exports (300.3 million m^3) were only 2% less than global imports (305.9 million m^3). Underreporting of tropical log exports thus does not appear to be substantial.

Table 6 Regression results: FE estimates of inverse recovery rate

Variable	Linear: only Integrity	Linear: both indices	Quadratic
Integrity	−0.01 (0.33)	0.16 (0.37)	1.02 (1.27)
Integrity^2	–	–	−0.95 (1.20)
Stability	–	−0.50 (0.58)	1.38 (1.92)
Stability^2	–	–	−1.53 (1.47)
Price ratio[a]	−0.097 (0.079)	−0.10 (0.082)	−0.11 (0.084)
Time trend	−0.033*** (0.008)	−0.027*** (0.011)	−0.028*** (0.012)
N	564	564	564
n	46	46	46
R^2 (within)	0.01	0.01	0.01

Dependent variable: inverse recovery rate (ratio of apparent consumption of sawlogs and veneerlogs to production of solid-wood products)
[a] Ratio of sawlog/veneerlog price to sawnwood price

3.2 Simulation of Improved Governance in Larger Timber-Producing Countries

To assess the magnitude of the impact of governance on harvests at a country level, we simulated the impacts of hypothetical improvements in governance on 2006 harvests in the larger timber-producing countries. We used coefficient estimates from the model in the last column of Table 4 in the calculations. Due to missing data, the simulation included 30 countries instead of the 33 in the estimation sample.[26] We simulated the impacts of increasing *Integrity* and *Stability* to the maximum 2006 values $(\widehat{I}, \widehat{S})$ among these countries, which were $\widehat{I} = 0.833$ (South Africa) and $\widehat{S} = 0.729$ (Malaysia). Expressed as a percentage, the predicted change in harvest was calculated as

$$100 \times \left(e^{\left(\hat{\beta}_I \widehat{I} + \hat{\beta}_{II} \widehat{I}^2 - \hat{\beta}_I I_i - \hat{\beta}_{II} I_i^2\right) + \left(\hat{\beta}_S \widehat{S} + \hat{\beta}_{SS} \widehat{S}^2 - \hat{\beta}_S S_i - \hat{\beta}_{SS} S_i^2\right)} - 1 \right). \tag{4}$$

The direction of the change depends on the level of a country's indices relative to not only the maximum values but also the turning points (0.487 for *Integrity*, 0.734 for *Stability*). For example, the predicted change is negative (harvests fall) in countries with indices above the turning points but positive (harvests rise) in countries with indices below both the turning point and the maximum value.

Table 7 shows the results. The countries are ordered from highest to lowest combined impacts of the hypothetical improvements in the two indices. The combined impacts vary greatly across the countries. Harvests are predicted to fall in two-thirds of the countries, which is consistent with the conventional wisdom about the impact of governance. This result is due entirely to the improvement in *Integrity*, as *Stability* is below the turning point in all the large producers. Improvements in the two indices tend to be offsetting: improvements in *Integrity* tend to reduce harvests, while improvements in *Stability* raise them. Countries with predicted increases in harvests are generally either ones with very unstable governments (e.g., Democratic Republic of Congo, Ghana, Paraguay) or relatively unstable governments with very low *Integrity* levels (e.g., Indonesia, Philippines, Uganda). The very large increase

[26] Ethiopia, Mozambique, and Vietnam were the three countries with missing 2006 data.

Table 7 Impact of hypothetical improved governance on harvests in larger timber-producing countries

Country	Governance index in 2006:		Impact on harvest (%):		
	Integrity	Stability	Integrity only	Stability only	Combined
Congo (Dem. Rep.)	0.056	0.167	12.4%	57.3%	69.7%
Ghana	0.144	0.292	−0.2%	28.4%	28.1%
Paraguay	0.208	0.292	−7.0%	26.5%	19.4%
Philippines	0.139	0.375	0.3%	18.0%	18.3%
Uganda	0.111	0.472	3.9%	9.5%	13.4%
Pakistan	0.271	0.302	−11.9%	23.7%	11.8%
Chile	0.623	0.302	−16.2%	22.6%	6.3%
Indonesia	0.139	0.542	0.3%	4.9%	5.2%
Iran	0.343	0.354	−15.9%	17.1%	1.2%
South Africa	**0.833**	0.726	0.0%	0.0%	0.0%
Gabon	0.361	0.368	−16.6%	15.6%	−1.0%
Cameroon	0.451	0.378	−18.7%	14.3%	−4.4%
Malaysia	0.787	**0.729**	−5.1%	0.0%	−5.1%
Tanzania	0.310	0.476	−14.3%	7.6%	−6.7%
Peru	0.287	0.510	−13.0%	5.8%	−7.2%
Uruguay	0.417	0.441	−18.2%	9.5%	−8.7%
Korea (Rep.)	0.584	0.458	−17.5%	8.4%	−9.1%
Brazil	0.639	0.510	−15.6%	5.6%	−10.0%
Kenya	0.370	0.510	−16.9%	5.5%	−11.4%
Argentina	0.537	0.503	−18.5%	5.7%	−12.8%
Costa Rica	0.667	0.667	−14.2%	0.5%	−13.7%
Côte d'Ivoire	0.579	0.552	−17.7%	3.6%	−14.1%
Papua New Guinea	0.639	0.724	−15.6%	0.0%	−15.6%
Thailand	0.542	0.576	−18.5%	2.6%	−15.8%
India	0.525	0.594	−18.7%	2.1%	−16.6%
Ecuador	0.556	0.611	−18.2%	1.6%	−16.6%
Mexico	0.556	0.667	−18.2%	0.5%	−17.7%
Colombia	0.509	0.635	−18.8%	1.0%	−17.8%
China	0.536	0.708	−18.6%	0.1%	−18.5%
Venezuela	0.500	0.708	−18.9%	0.1%	−18.8%

Hypothetical improvements: governance indices increase to maximum 2006 values (0.833 for Integrity, 0.729 for Stability)

for the Democratic Republic of Congo receives anecdotal support from a prediction by a conservation biologist with the Wildlife Conservation Society: "Just wait until things stabilize. Wait until the big loggers think it's safe to move in. That's when the real plunder begins" (Salopek 2005, p. 91).

4 Discussion

We have presented empirical evidence that improved governance can cause commercial timber harvests in developing countries either to rise or to fall, not simply to fall, which appears to be the conventional wisdom. This nonmonotonic impact is consistent with resource economics theory, which predicts that the impact of risk on resource extraction depends on the relative strengths of two countervailing forces, a depletion effect and an investment effect. Previous empirical research on governance in the forest sector has focused on deforestation. It has found that improved governance reduces deforestation, but logging and deforestation are not identical economic activities. Most deforestation results from agricultural expansion, not logging, and deforestation tends to be less capital-intensive than logging. The literature on the impact of corruption (one important dimension of governance) on investment emphasizes the production-enhancing impact of improved governance. Empirical evidence of such an impact has been reported for petroleum, but oil production is considerably more capital-intensive than logging. The impact of improved governance on timber harvests might thus be expected to differ from other natural resource-related impacts that have been previously reported.

Our econometric analysis revealed that it does differ. We investigated two dimensions of governance, integrity (a composite of corruption, bureaucracy quality, and law and order) and stability (a composite of government stability and democratic accountability). Both indices had a nonmonotonic impact, with marginal improvements in governance along either dimension tending to raise harvests when governance is weaker (thus resembling the impact on petroleum) but to reduce harvests when governance is stronger (thus resembling the impact on deforestation). The investment effect appears to dominate when governance is weaker (a shortage of capital constrains harvests), while the depletion effect appears to dominate when governance is stronger (loggers are less myopic). This nonmonotonic relationship is robust to the inclusion or exclusion of fixed effects and neoclassical timber-supply variables. It is implied by not only a quadratic model but also more flexible specifications (linear spline and dummy variable models). An analysis of inverse recovery rates indicates that it is not a spurious relationship resulting from an underreporting of harvests when governance is weak.

We used the econometric results to predict the impacts of non-marginal improvements in governance for larger timber-producing countries in 2006. Due to differences in the turning points for the two indices and in the observed levels of the indices compared to the hypothetical higher values, we found that improvements in governmental integrity would tend to reduce harvests while improvements in stability would raise them. The net impact in most countries was for harvests to fall. This supports the conventional wisdom. For countries that were very unstable or combined instability with very low integrity, however, improved governance was predicted to result in higher harvests. The increases were substantial in some cases ($>20\%$).

Our estimates of the impact of improved governance could be conservative ones for several reasons: (i) measurement error resulting from our use of economywide governance indicators instead of ones specific to the forest sector, which biases the coefficient estimates on the governance indices toward zero; (ii) our use of fixed effects to control for unobserved cross-country variation, which eliminates between-country variation in the governance indices; and (iii) the predictions in Table 7 do not account for indirect impacts of governance on harvests resulting from the potential impacts of governance on the neoclassical timber-supply variables, such as prices and the interest rate. On the other hand: (i) our analysis of responses to the World Business Environment Survey suggests that economywide indicators might differ little from ones for a sector that includes logging, and economywide indicators are less likely to be simultaneously determined with timber harvests; (ii) although the standard deviation of the within-country component of the governance indices is less than the overall standard deviation, it is more than half as large (and comparable to the between-country component);

and (iii) coefficient estimates on the governance variables in models that exclude the neoclassical variables, which can be viewed as being closer to reduced-form estimates, are not consistently larger than estimates in models that include those variables. Our estimates might therefore not be too conservative.

We emphasize that our analysis is purely positive. It provides no normative information on the welfare impacts of changes in timber harvests that could result from improved governance. Logging generates economic benefits through increased wages, profits, and government revenue, but it can also generate economic costs through negative environmental externalities. The balance between the benefits and costs of logging likely varies from country to country. We can, however, identify one broad policy implication of our analysis: even if a reduction in harvests is clearly desirable from a welfare standpoint, improved governance is not necessarily a means to that end. A program to improve governance could instead result in greater harvests, especially in countries with very weak governance. In such cases, programs to improve governance need to be coupled with more targeted programs to monitor logging activities and to take action when harvests exceed desired limits.

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Appendix

See Tables 8, 9, and 10.

Table 8 90 countries included in Models (1) and (2)

Algeria, Angola, **Argentin**a, Armenia, Azerbaijan, *Bahamas*, Bangladesh, Bolivia, Botswana, **Brazil**, Brunei, Burkina Faso, **Cameroon**, **Chile**, **China**, **Colombia**, **Congo (Dem. Rep.)**, *Congo (Rep.)*, **Costa Rica**, **Côte d'Ivoire**, *Cuba*, *Cyprus*, Dominican Republic, **Ecuador**, *Egypt*, El Salvador, **Ethiopia**, **Gabon**, Gambia, **Ghana**, Guatemala, Guinea, Guinea-Bissau, Guyana, *Haiti*, Honduras, **India**, **Indonesia**, **Iran**, *Iraq*, *Israel*, Jamaica, *Jordan*, *Kazakhstan*, **Kenya**, *Korea (Dem. People's Rep.)*, **Korea (Rep.)**, *Lebanon*, *Liberia*, *Libya*, Madagascar, Malawi, **Malaysia**, Mali, **Mexico**, Mongolia, **Morocco**, Mozambique, *Myanmar*, *New Caledonia*, Nicaragua, Niger, *Nigeria*, **Pakistan**, Panama, **Papua New Guinea**, **Paraguay**, **Peru**, **Philippines**, Senegal, *Sierra Leone*, *Somalia*, **South Africa**, Sri Lanka, *Sudan*, Suriname, Syria, **Tanzania**, **Thailand**, Togo, Trinidad and Tobago, *Tunisia*, *Turkey*, **Uganda**, **Uruguay**, *USSR*, **Venezuela**, **Vietnam**, Zambia, Zimbabwe

Italics: 23 countries excluded from Model (3) due to incomplete data
Bold: 33 larger timber-producing countries

Table 9 Definitions of PRS governance indicators

Indicator	Definition
Corruption	Low scores indicate "excessive patronage, nepotism, job reservations, 'favor-for-favors', secret party funding, and suspiciously close ties between politics and business" and/or "financial corruption in the form of demands for special payments and bribes connected with import and export licenses, exchange controls, tax assessment, police protection, or loans."

Table 9 continued

Indicator	Definition
Bureaucracy quality	High scores indicate "an established mechanism for recruitment and training," "autonomy from political pressure," and "strength and expertise to govern without drastic changes in policy or interruptions in government services" when governments change
Law and order	Indicates the "popular observance of the law" and the "strength and impartiality of the legal system."
Government stability	Indicates both "the government's ability to carry out its declared program(s)" and "its ability to stay in office."
Democratic accountability	Indicates how responsive government is to its people; low scores indicate "the more likely [it] is that the government will fall, peacefully in a democratic society, but possibly violently in a non-democratic one."

Source: International Country Risk Guide (2004)

Table 10 Regression results: FE estimates of diesel price

Variable	Estimates
ln(Oil price)	0.44*** (0.028)
GDP deflator	−0.023 (0.087)
N	522
n	84
R^2 (within)	0.30

Dependent variable: natural logarithm of diesel price (2000 US$/l)
Two-tailed test: *** significant at 0.01, ** at 0.05, * at 0.1. Newey-West standard errors in parentheses
Sample period: 1991, 1993, 1995, 1998, 2000, 2002, 2004, 2006

References

Alexeev M, Conrad R (2009) The elusive curse of oil. Rev Econ Stat 91(3):586–598

Barbier EB, Damania R, Léonard D (2005) Corruption, trade, and resource conversion. J Environ Econ Manage 50:276–299

Bardhan P (1997) Corruption and development: a review of issues. J Econ Lit 35:1320–1346

Binkley CS (1987) Economic models of timber supply. In: Kallio M, Dykstra D, Binkley CS (eds) The global forest sector: an analytical perspective. Wiley, Chichester

Binkley CS, Dykstra D (1987) Timber supply. In: Kallio M, Dykstra D, Binkley CS (eds) The global forest sector: an analytical perspective. Wiley, Chichester

Bohn H, Deacon RT (2000) Ownership risk, investment, and the use of natural resources. Am Econ Rev 90:526–549

Bulte E, Damania R (2008) Resources for sale: corruption, democracy and the natural resource curse. BE J Econ Anal Policy 8(1):Article 5

Chomitz KM (2007) At loggerheads? Agricultural expansion, poverty reduction, and environment in the tropical forests. World Bank, Washington DC

Collier P, Hoeffler A (2004) Conflicts. In: Lomborg B (ed) Global crises, global solutions. Cambridge University Press, Cambridge

Dasgupta PS (1982) The control of resources. Harvard University Press, Cambridge

Dasgupta PS, Heal GM (1979) Economic theory and exhaustible resources. Cambridge University Press, Cambridge

FAO (1995) Forest resources assessment 1990. Rome

FAO (2001a) Global forest resources assessment 2000. Rome

FAO (2001b) State of the world's forests 2001. Rome

FAO (2005) Global forest resources assessment 2005. Rome

FAO (2007) State of the world's forests 2007. Rome

Farzin YH (1984) The effect of the discount rate on depletion of exhaustible resources. J Polit Econ 92:841–851
Geist HJ, Lambin EF (2001) What drives tropical deforestation? A meta-analysis of proximate and underlying causes of deforestation based on subnational case study evidence. LUCC Report Series 4, IHDP and IGBP, Louvain-la-Neuve, Belgium
Humphreys M, Bates RH (2005) Political institutions and economic policies: lessons from Africa. Brit J Polit Sci 35:403–428
International Country Risk Guide (2004) Researchers dataset. PRS Group, East Syracuse
Jain AK (2001) Corruption: a review. J Econ Surv 15:71–121
Johnston M (2001) Measuring corruption: numbers versus knowledge versus understanding. In: Jain AK (ed) The political economy of corruption. Routledge, London
Kaufmann D, Kraay A, Zoido-Lobaton P (1999a) Aggregating governance indicators. Policy Research Working Paper 2195, World Bank, Washington DC
Kaufmann D, Kraay A, Zoido-Lobaton P (1999b) Governance matters. Policy Research Working Paper 2196, World Bank, Washington DC
Kaufmann D, Kraay A, Zoido-Lobaton P (2009) Governance matters VIII: Aggregate and individual governance indicators 1996-2008. Policy Research Working Paper 4978, World Bank, Washington DC
Kennedy P (1992) A guide to econometrics. 3. MIT Press, Cambridge
Knack S (2002) Governance and growth: measurement and evidence. In: Paper presented at forum series on the role of institutions in promoting economic growth, IRIS Center, University of Maryland, College Park, February 25, 2002
Knack S, Keefer P (1995) Institutions and economic performance: cross-country tests using alternative institutional measures. Econ Polit 7:207–227
Lambsdorff JG (2003) How corruption affects persistent capital flows. Econ Governance 4:229–243
McKillop WL (1967) Supply and demand for forest products: an econometric study. Hilgardia 38:1–132
Mauro P (1995) Corruption and growth. Q J Econ 110:681–712
Mauro P (1997) The effects of corruption on growth, investment, and government expenditure: a cross-country analysis. In: Kimberly AE (ed) Corruption and the global economy. Institute for International Economics, Washington DC
Mundlak Y (1978) On the pooling of time series and cross section data. Econometrica 46(1):69–85
Page JM, Pearson SR, Leland HE (1976) Capturing economic rent from Ghanaian timber. Food Res Inst Stud 15:25–51
Robinson JA, Torvik R, Verdier T (2006) Political foundations of the resource curse. J Dev Econ 79:447–468
Rose-Ackerman S (2004) Governance and corruption. In: Lomborg B (ed) Global crises, global solutions. Cambridge University Press, Cambridge
Ross M (2001) Timber booms and institutional breakdown in Southeast Asia. Cambridge University Press, Cambridge
Ruzicka I (1979) Rent appropriation in Indonesian logging: East Kalimantan 1972/3–1976/7. B Indones Econ Stud 15:45–74
Salopek P (2005) Who rules the forest? Natl Geogr 208(3):74–95
Seneca Creek Associates and Wood Resources International (2004) "Illegal" logging and global wood markets: the competitive impacts on the U.S. wood products industry. Report prepared for the American Forest & Paper Association
Smith J, Obidzinski K, Subarudi I, Suramenggala (2003) Illegal logging, collusion, corruption and fragmented governments in Kalimantan, Indonesia. Int For Rev 5:293–302
Stone SW (1998) Evolution of the timber industry along an aging frontier: the case of Paragominas (1990–95). World Dev 26:433–448
Timmer CP, Akkus S (2008) The structural transformation as a pathway out of poverty: analytics, empirics and politics. Working Paper No. 150, Center for Global Development, Washington DC
Vincent JR (1990) Rent capture and the feasibility of tropical forest management. Land Econ 66:212–226
World Bank (2004) Sustaining forests: a development strategy. World Bank, Washington DC
Zinnes C, Alevy J, Vincent JR (2007) The impact of restitution on sustainable forest use in Romania. Report prepared for US Department of Agriculture (contract 58-3148-4-079), IRIS Center, University of Maryland, College Park