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Oil, Macroeconomics, and Forests: Assessing the Linkages

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How does an oil boom affect the forest cover of tropical oil-exporting countries? What macroeconomic linkages and policies are decisive? A comparison of research findings on long-run land-use changes in eight tropical developing economies reveals that the direct physical impacts of the oil industry on forests are unquestionably less than its derived macroeconomic impact. In most cases oil wealth indirectly but significantly protects tropical forests. The core mechanism is that oil rents cause macroeconomic "Dutch disease" decreasing the price competitiveness of agriculture and logging, strongly diminishing pressures for forest degradation and deforestation. But domestic policy responses to oil wealth are also vital determinants of the forest outcome. When governments use oil wealth for urban spending sprees, this reinforces the core effect by pulling more labor out of land-using and forest-degrading activities. When oil revenues finance road construction or frontier colonization, however, the core forest-protective effect can be reversed. Repeated currency devaluation and import protection of land-using domestic sectors also increase pressures on forests. Other international capital transfers, like bilateral credits, aid, or debt relief, can have impacts similar to those of oil wealth, either alleviating pressures on forests or aggravating specific forest-detrimental policies. These insights point to forest-friendly safeguards that can realistically be made in the design of structural adjustment programs, considering the important tradeoffs between development and conservation objectives.

Over the past decade there has been growing interest in the relationship between macroeconomics and the environment, including the links to deforestation and forest degradation. This is due to a growing recognition that the fate of tropical forests is determined by factors outside forests and the forestry sector, factors which have often been called the underlying causes of deforestation (Contreras-Hermosilla 2000). A wealth of theoretical economic models has been developed, with multi-country regression models as the predominant category (Angelsen and Kaimowitz

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1999). However, the United Nations Food and Agriculture Organization (FAO) deforestation data normally used in these exercises are highly problematic (see later discussion). Thus, it is dubious to what extent the observed cross-country patterns can be given a time-series interpretation (Kaimowitz and Angelsen 1998). Cross-country analysis should thus be complemented by country-comparative case studies (Kaimowitz and others 1998; Reed 1992, 1996; Wood and others 2000). These studies, however, have analyzed mostly short-run effects of macroeconomic change, notably the environmental effects of structural adjustment.

The comparative research described here was conducted by the Center for International Forestry Research (CIFOR) and is documented more extensively elsewhere (Wunder 2003b). It looks at the macroeconomic determinants of changes in land use and forest cover since the 1970s. Eight developing economies with tropical forests were analyzed, five with detailed case studies (Cameroon, Ecuador, Gabon, Papua New Guinea, and Venezuela) and referred to as primary cases and three (Indonesia, Mexico, and Nigeria) with more summary-type or secondary case studies. The countries were selected to cover a variety of conditions, including geographic location, country size, income per capita, and proportion of forest coverage. A subsidiary criterion was the existence of previous CIFOR research on land-use change (Cameroon, Indonesia, and Ecuador).

This article focuses mainly on the five primary case study countries. For forest impacts, the concentration is on forest conversion to other land uses and deforestation, defined as a (temporary or permanent) removal of trees to less than 10 percent crown cover, which is similar to the FAO's definition (FAO 2000). Selective logging is thus not deforestation but may degrade forests and enable conversion. The link from oil wealth and macropolicies to logging and forest degradation is analyzed elsewhere (Wunder 2003a).

All of the case study countries are tropical countries that export oil, a choice made for two reasons. First, the macroeconomic "laboratory" of oil exporters offers a good opportunity to study links between external economic changes and forests. Oil economies often fluctuate dramatically due to heavy reliance on a single export commodity with unstable world market prices. The policy responses to frequent boom and bust cycles also differ enormously, both over time and across countries (Bevan and others 1999a; Collier, Gunning, and Associates 1999; Little and others 1993; Neary and van Wijnbergen 1986). This is because oil wealth buys governments higher degrees of freedom in defining individual policy responses (Gelb and Associates 1988; Karl 1997). This large variation makes it easier to track the eventual effects of different policies on forests.

Second, earlier studies provide support for the hypotheses that on average oil- and mineral-exporting tropical countries have more forests left and lose them at a slower rate than nonmineral-exporting countries. This is true not only for a bivariate group comparison but also for multivariate cross-country deforestation models controlling for third causal factors (Mainardi 1998; Sunderlin and Wunder 2000). The FAO's *Forest Resource Assessment 2000* data indicate that specialized mineral exporters, which derive more than 50 percent of their export revenues from oil and minerals, have no less than 47.7 percent of the area of remaining tropical forests (Wunder 2003b:chap. 2). This estimate is fairly conservative.[1] In other words, the cross-country data suggest that there are some characteristics of oil and mineral economies that in most (but not all) cases inadvertently protect forests. This article seeks to explain this forest-protecting mechanism and understand how it is affected by domestic policy responses. The core hypothesis is that in the oil-exporting countries, deforestation pressures are lower when oil revenues are booming than during oil bust periods. This shifts the reasoning from a static cross-country framework to an intertemporal, comparative one.

The article briefly reviews hypotheses and methodologies and outlines the deforestation data problems and how they were dealt with. It presents empirical results for the five primary case study countries and takes a closer look at three of the key causal linkages in the model. It then examines the role of different policy instruments and finally discusses policy insights that extend beyond the oil-exporting countries.

Theories and Methods

Why should oil wealth reduce pressures on forests? Sizable foreign exchange earnings from oil, sometimes supplemented by foreign borrowing, raise government spending, increasing aggregate demand. This causes the real exchange rate to appreciate through growing inflation and nominal currency revaluation. Nontraded and quasi-nontraded (import-protected) sectors expand, while nonoil traded goods lose competitiveness and decline. This is the classical Dutch-disease pattern (Corden 1984), named after the Netherlands' experience with gas revenues in the 1960s and 1970s (*The Economist* 1977).

In developing economies, primary sectors have been the main victims of Dutch disease, especially agriculture and the "purely traded" export sectors (Collier, Gunning, and Associates 1999; Neary and van Wijnbergen 1986; Roemer 1984). To the extent that large parts of the agricultural and timber sectors are exposed to foreign competition, an oil boom generally discourages the expansion of agriculture and logging. That also tends to reduce area expansion in these sectors and hence curbs deforestation for agricultural conversion and for a number of other primary activities that potentially claim forested lands (shrimp farming, small-scale mining).

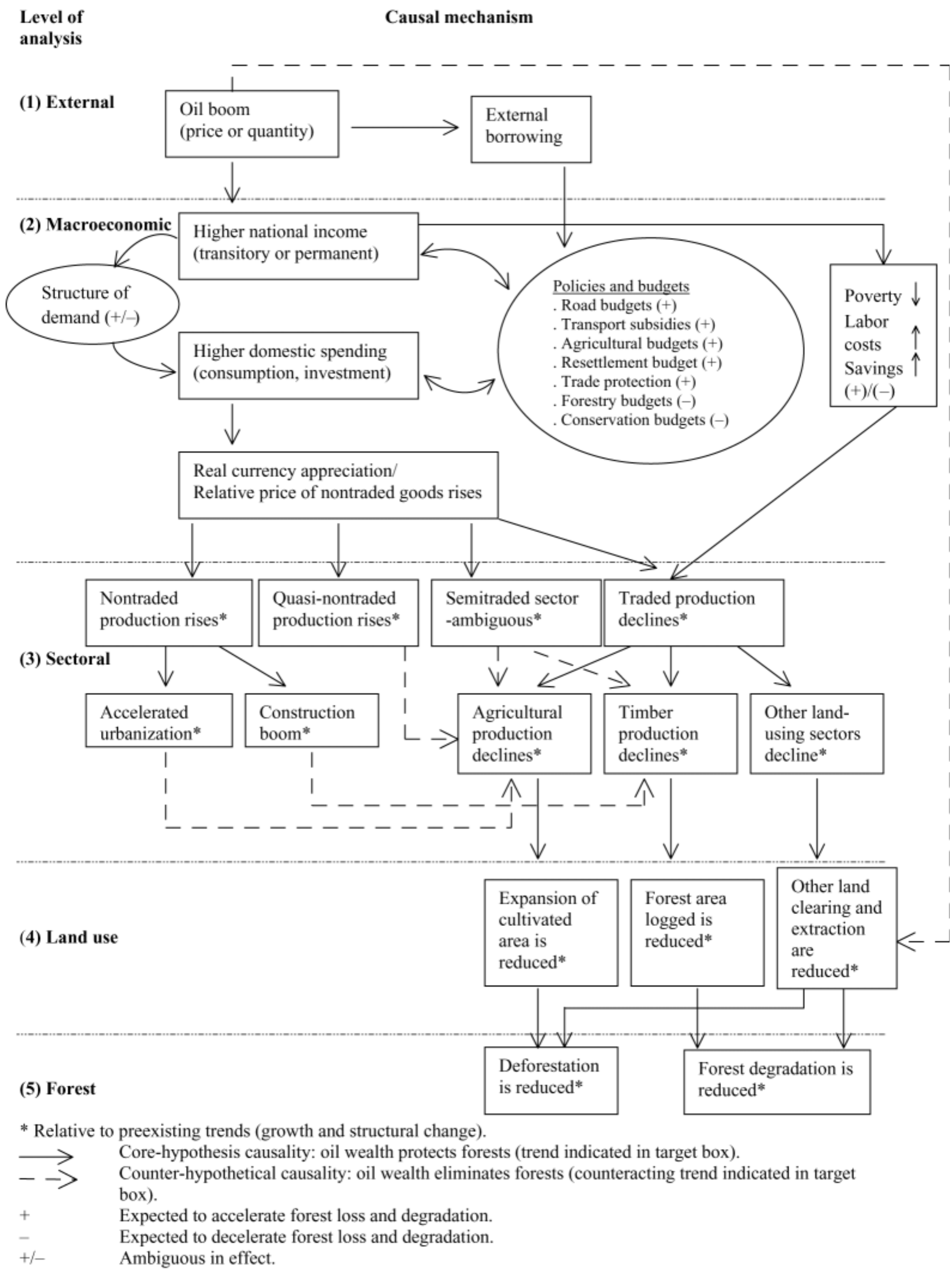
What impact has there been on forests from the oil-led expansion of the nontradable sectors? Most nontradables (public and private services, construction, and so on) and trade-protected quasi-nontradables (manufacturing) are urban, so most oil booms are accompanied by accelerated urbanization. Rural labor is drawn to the cities, abandoning natural-resource based livelihoods for urban activities that tend to have more benign forest impacts. Conversely, in times of urban crisis some of these people return to their villages, reexpanding food-crop production into forests as a default rural safety net. Growing cities also leave "ecological footprints" on forests, through demand for timber for construction, fuel wood for cooking, or protein-rich foods (meat, dairies) that can lead to forest conversion. Often peri-urban forests are most affected by these pressures. Still, urban sprawl in itself was a negligible source of deforestation in the case study countries.[2] In most cases, agricultural production for urban markets also became more sedentary and land-intensive (fewer land inputs per unit of output), and part of urban demand was also satisfied through imports.[3] Rapid urbanization is therefore good news for the conservation of a country's forest cover in most cases.[4]

As this rudimentary overview shows, it is important to take into account a variety of linkages between macroeconomic factors and forests. In a recent analogous study on the root causes of biodiversity loss, all macro-level changes were assumed to jeopardize biodiversity (Wood and others 2000). But it is more realistic to assume that some underlying factors increase environmental pressure whereas others reduce it, the net effect depending on the balance between them. One way of analyzing multi-level linkages with opposing forest cover effects is to use a computable general equilibrium (CGE) model (see Kaimowitz and Angelsen 1998:61–68, for an overview). However, such models have difficulty dealing with the spatial specificity of deforestation. They also generally require a wealth of information. The data gaps for the case study countries proved to be too large to use a CGE model without first bridging data gaps by making "creative" CGE parameter assumptions. For the sake of greater transparency, a partial recursive approach was used instead (figure 1).

The analysis runs from the external level (1) of foreign-exchange inflows and the macroeconomic level (2) down to sectoral production (3), land use (4), and the forest levels (5). At the external level when oil wealth, or foreign borrowing against future oil revenues, finances large increments in road budgets or resettlement projects or subsidies for transport or agriculture, forest loss may increase (marked by a plus sign in figure 1). The opposite could be the case if budget allocations for conservation and forestry regulations are strengthened (marked by a minus sign).

Structural changes outside the policy sphere also affect the forest outcome in an ambiguous way (left side of figure 1). For instance, if higher incomes induce consumers to buy more meat and dairy products, that tends to increase deforestation for cattle raising, as in Latin America. But if higher income leads to a shift from tubers produced on swidden land to more land-intensive rice production, that can reduce forest loss, as in Central Africa. Reduced poverty in a booming economy goes hand in hand with higher labor costs (reducing deforestation), but there will also be more funds available for investment, which can promote more forest clearing in capital-scarce frontiers (right side). The relative strength of these counterhypothetical,

Figure 1. Linking Resource Booms to Forest Cover Outcomes



Source: Authors' construction.

forest-eliminating partial effects differs from case to case (dotted lines in figure 1). In addition, there is the macroeconomic Dutch disease effect described already (center-left), causing real currency appreciation and changes in relative prices.

At the sectoral level (3) Dutch disease causes traded sectors to decline while non-traded (services, construction) and quasi-nontraded sectors (industry) rise. If timber production and agriculture are fully traded sectors with perfect foreign substitutes, Dutch disease at the land-use level (4) will unambiguously alleviate pressures to log new forest areas and convert forests to agriculture and other traded-sector land uses (such as shrimp farming impacting mangroves)—at least compared with pre-existing sectoral trends. If these extrasectoral effects are dominant in their impact on forests (5), deforestation and forest degradation would also be reversed or at least reduced. Whether the forest-protection effect is proportional to the land-use effect depends on specific parameters, such as the number of species extracted per hectare or the extent to which abandoned agricultural areas convert back into forests.

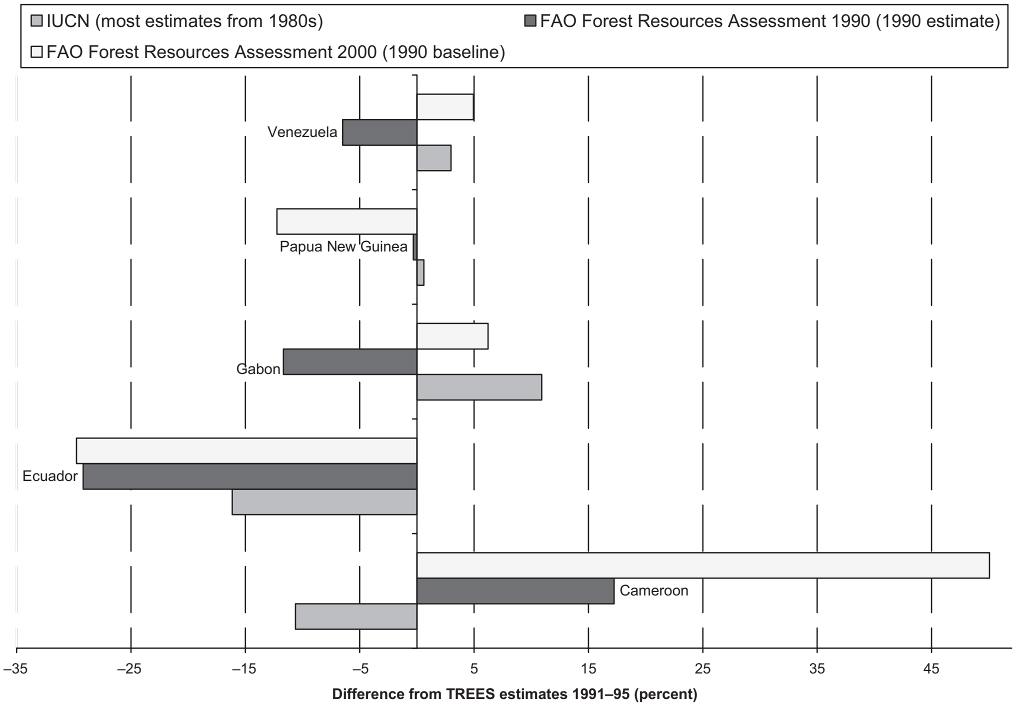
Contrary effects may occur to the extent that logging and agriculture are semi-traded or quasi-nontraded, for example, through import protection of part of the sector. In that case greater urbanization may cause a construction boom with higher domestic timber demand or a beef-and-dairy boom accelerating deforestation for domestic ranching. The partial approach does not produce a bottom-line calculus of whether these contrary effects in net terms reverse the forest-protecting effect. Yet it is a flexible framework for pulling together the patchwork of land-use factors, in spite of incomplete data coverage and variable spatial scenarios.

Deforestation and Land-Use Data

Although hundreds of deforestation models and analyses have been developed over the past decade, country-level statistics on forests and deforestation tend to be lacking or unreliable. The adequacy of FAO forest statistics, the most frequently used source, has been discussed critically elsewhere (Grainger 1996; Matthews 2001; Rudel and Roper 1997). Here, observations concern only the five case study countries. A comparison of forest stock estimates from the European Union's TREES project for the early 1990s with those from FAO (FAO 1993, 2001) and the World Conservation Union (IUCN) reveals typical stock variations in the 5–15 percent range, but the gap can be 30–50 percent for countries with large forest-savannah transition zones, such as Cameroon, or forest fragments in deforested landscape, such as Ecuador (figure 2 and table 1).[5] Accounting for much of these large disparities are differences in canopy cover criteria, spatial scales of resolution, time scale, and sample coverage (Wunder 2003b:chap. 3).

There are no annual deforestation estimates for any of the case study countries, and it is thus not possible to do a proper testing of time-series relationships. The FAO

Figure 2. Differences in FAO and IUCN Tropical Forest Cover Estimates from TREES Estimates



Note: TREES estimates are from maps between 1991 and 1995.

Source: TREES (Mayauxand others 1998); IUCN *Conservation Atlas* figures cited in Mayaux and others (1998); FAO 1990 estimates (FAO 1993:table 1); FAO 1990 baseline (FAO 2001).

produces average deforestation estimates for every full decade, but even these tend to be highly problematic for the case study countries. The deforestation figures from *Forest Resources Assessment 2000* (FAO 2001) for the 1990s are strikingly different from those for the 1980s in *Forest Resources Assessment 1990* (FAO 1993). The difference is explained more by changing methods and assumptions than by measured differences. According to these data, forest cover loss appears to have doubled in the 1990s in Cameroon and decreased by two-thirds in Venezuela and by more than 90 percent in Gabon. Papua New Guinea's annual forest loss remains at 113,000 ha, but *Forest Resources Assessment 2000* retrospectively set deforestation in the previous period (1975–85) to zero, so that the flow estimate would still be compatible with the new forest stock figures. For Venezuela the large reduction in estimated deforestation reflects the changes in methods from a population-based model prediction to a national expert consensus around a much more conservative figure. As explained in the notes to table 1, *Forest Resources Assessment 2000* deforestation figures are based

Table 1. Comparing Forest Cover Estimates: FAO's Forest Resources Assessment (FRA) 2000 and 1990 and Authors' Estimates (thousands of ha unless otherwise noted)

	FRA 2000				*FRA 1990*			*Difference in 1990 forest area between FRA 2000 and FRA 1990*		*Authors' "best guess"*	
Country	*Total forests 2000*[a]	*Annual deforestation 1990–2000*	*Annual deforestation rate 1990–2000(%)*	*Baseline 1990*[a]	*Total forests 1990*[a]	*Annual deforestation 1980–90*	*Annual deforestation rate 1980–90 (%)*	*%*	*Number of deforestation years (FRA 2000)*	*Forest c over ~1990*[a, b]	*Deforestation 1990s*
Cameroon	23,858	222[c]	0.9	26,078	20,372	122	0.6	28.0	26	17,000–24,000	150–200
Ecuador	10,557	137[d]	1.2	11,927	12,026	238	1.8	–0.9	–1	15,500 (11,500–17,000)	>180
Gabon	21,862	10[e]	0.0	21,962	18,265	116	0.6	20.2	370	20,500–23,000	0
Papua New Guinea	30,601	113[f]	0.4	31,731	36,043	113	0.3	–12.0	–38	32,000–37,000	50–70
Venezuela	49,506	218[g]	0.4	51,686	46,052	599	1.2	12.2	26	49,000 (44,000–49,000)	250–400

Source: FAO (1993, 2001); online data at www.fao.org/forestry/fo/country/index.jsp (accessed 31 July 2001); and authors' estimates.

[a]Including plantations.

[b]Preferred point estimate or likely range under variable assumptions and definitions.

[c]Cameroon, 1975–99 interpolation and extrapolation.

[d]Ecuador, 1985–92 interpolation and extrapolation.

[e]Gabon, 1970–99 interpolation and extrapolation.

[f]Papua New Guinea, 1975–2000 interpolation.

[g]Venezuela, 1985–95 interpolation and extrapolation.

on long-term interpolation and extrapolations from other decades, so at best they say something about forest loss in the recent past rather than specifically in the 1990s.

If the amount of forest lost in the study countries is unknown, along with how the pace of loss has changed in subperiods, how can the causes of forest loss be estimated? The analysis here employs what FAO calls the "convergence of evidence" method. This involves gathering all available data and using basic math and common sense to deduce what land-use changes are most likely to have occurred. All national estimates, subnational trends specified in two global deforestation study databases (Geist and Lambin 2001; unpublished collection of Thomas Rudel) and country sources, and trends in predesignated deforestation "hot spots" were critically examined. For Cameroon, primary data gathered for a CIFOR project were used, providing three- to four-period estimates. Following Houghton and others (1991) and Barbier (2001), cultivated area expansion was also examined as an alternative deforestation indicator. Except for the savannah regions of northern Cameroon and the Llanos region in Venezuela, most unoccupied land in the study countries is forested, and by far most forest loss can be attributed to the expansion of agriculture (including livestock).

Estimates of deforestation in the 1990s for the five primary case study countries based on this screening of a large number of land-use sources are reported in the last column of table 1. In some cases, estimated ranges were preferred to point estimates. For Cameroon, Ecuador, and Venezuela the estimates fall between those of *Forest Resources Assessment 1990* and *Forest Resources Assessment 2000*; for Gabon and Papua New Guinea the estimates are significantly lower than both FAO figures. Despite the absence of hard data (except for Cameroon), this yielded a rough idea of historical forest trends. This article is limited to simply identifying periods of "high" or "low" forest loss and employing them in the analysis below. (Wunder 2003b:chaps. 4–9, provides a detailed quantitative assessment of the intricate picture of land-use changes and deforestation in each of the study countries.)

The country-specific land-use screening exercises also gave a clear indication of the uses to which converted forestlands were being put. Although agriculture was always the principal alternative land use, the types of land-hungry subsectors differed greatly across the cases. In Ecuador and Venezuela, pastures for cattle ranching were overwhelmingly dominant. In Cameroon, Gabon, and Papua New Guinea, extensive swidden food crop systems were the primary land use. The multitude of export crops grown in Cameroon accounted for only a minor share of deforested area, because in Cameroon export crops are cultivated in a more land-intensive manner than food crops.

The screening also gave a more realistic view of which sectors were definitely not to blame for the bulk of deforestation. The direct land-conversion effects from oil and mining, judged to be a significant cause in some past campaigns to save the rainforest (RAN and Project Underground 1998; WWF 2002), were found to be negligible sources of forest loss. In Cameroon oil was produced off-shore. In Venezuela oil is mainly from nonforested savannahs. In Gabon most oil sources are in forests, but the industry occupies less than 10,000 ha (0.05 percent of forest area). In Papua New Guinea the industry occupies just 1,200 ha. In Ecuador 99 percent of oil production comes from the Amazon forest, but accumulated direct conversion has been only about 3,000–6,500 ha (0.04–0.09 percent of Ecuador's Amazon forest). Indirect access-provision and pollution effects have in some cases been much larger than the direct effects. But these effects were much reduced when the industries used best practice.

Country Stories

This section examines the five primary case study countries for evidence of the impact of oil wealth on forests.[6]

Gabon

Gabon provides a textbook case of confirmation of the core hypothesis. Its transformation to an oil exporter in the early 1970s gave this sparsely populated country the highest per capita oil rent in the case study countries. Despite a mini-bust in 1986–89 and highly fluctuating oil revenues in the 1990s, the entire post-1973 period was an era of high oil wealth.

Oil revenues, which were unequally distributed, caused massive, economywide structural changes. An appreciating real exchange rate eliminated smallholder cash crops like coffee and cocoa. Nontraded sectors thrived, in particular oil-financed public employment and urban construction. With the total neglect of rural areas and road building, and with substantial urban rent-seeking, there was a rural exodus of people in the most productive age groups. The agricultural lands they abandoned grew back into forest. A village chief in northeast Gabon describes a situation in which reduced cropping and lower human presence go hand in hand with forest rehabilitation: "Nobody lives here any more. . . . The young are leaving, and the elephants and gorillas run freely through our gardens, destroying what little we grow to eat."[7] A resettlement program that brought people out of the forest into concentrated roadside settlements (rather than moving them into the "empty" forestland) reinforced that trend.

Two national forest inventories indicate that high oil wealth likely led to a marginal absolute expansion of national forest area between 1970 (20,567,338 ha) and 1990 (20,677,000 ha; Wunder 2003b:86–90). For the 1990s FAO's *Forest Resources Assessment 2000* revised annual deforestation estimates downward to only 10,000 ha (0.05 percent). Within this overall picture, there were local deforestation processes in peri-urban areas, especially during recent mini-crises, when some people lost their urban jobs and increasingly turned to peri-urban "weekend farming" to improve their livelihoods. On the other hand, forests away from urban areas returned to abandoned agricultural lands, as indicated by a number of village case studies using remote sensing data (Wunder 2003b).

Should oil revenues begin to decline rapidly, reducing the real value of Gabon's currency, wages, and nontraded prices, there would be an increase in the domestic production of cash and food crops, which are now mostly imported from neighboring countries. Because most of Gabon is covered by forests, this higher land demand would be a significant stimulus to deforestation.

Venezuela

Venezuela's transformation from a specialized agricultural exporter in the 1920s to a mono-exporter of oil from the 1930s onward has many similarities to Gabon's story. It is another case that confirms the core hypothesis in absolute terms. National forest maps show marked net forest regrowth in abandoned agricultural areas from 1920–50, when people rushed into the cities to take advantage of economic opportunities arising from oil wealth. But in the 1950s Venezuela invested heavily in roads, which together with fuel subsidies greatly reduced the cost of transporting agricultural products. (Even in the early 1990s a liter of gasoline was cheaper than a liter of bottled water.) This promoted the expansion of the cattle sector, which has accounted for almost all of the country's expansion of cultivated area since World War II. Cultivated area expanded from 2.4 million ha in 1945 to 19.5 million ha in 1978. But 16.4 million ha (95.6 percent) of the 17.1 million ha expansion were for cultivated pasture and only 0.76 million ha (4.6 percent) for cropland. No pasture data were collected after 1978, but data on the number of cattle indicate that the strong expansion continued. By 1996 pastures accounted for 95 percent of cultivated-area expansion since 1945 (Wunder 2003b:144–47; data from the Ministry of Agriculture and Breeding).

Cattle ranching was a semi-traded sector, with import protection during some periods and for some products. It expanded procyclically with urban incomes due to higher demand for protein-rich food. Meanwhile, cropped area stagnated, despite large population growth. Unlike pasture, growth in cropped area was negatively correlated with both rising urban incomes and declining price competitiveness. In this sense, crop cultivation was the true victim of Dutch disease.

Although Venezuela still had low forest loss rates over 1950–80, both deforestation assessments and agricultural area data indicate that the loss has accelerated in the past two decades. With the deep economic and political crises of the 1980s and 1990s, the speed of forest extraction and clearing increased, even in the areas south of the Orinoco River that had previously been remote from the bustling urban centers. This spatial expansion was closely related to a depreciating real exchange rate, which stimulated logging, artisan mining, and even food crop cultivation. Since

World War II Venezuela has thus witnessed increasing forest loss, though still at a slower pace than its neighbors, which have stronger agricultural sectors.

Cameroon

Cameroon had the most pronounced economic cycles in the sample countries. The prosperity of 1978–85, with a convergence of high international prices for its main exportables (oil, coffee, and cocoa) and access to foreign capital, gave way to misery in 1986 when the external environment suddenly reversed sharply, with a collapse in world market prices for oil and crops and soaring real interest rates. During 1986–94 Cameroon could not unilaterally devalue the CFA franc, whose value was set at the regional level. This clearly intensified the economic crisis. Cameroon has been recovering slowly since the 50 percent CFA devaluation in 1994.

Specific analysis, tailored to compare the effects of boom and bust and with good coverage of the entire humid forest zone, allowed a more exhaustive evaluation of the core hypothesis. The boom (1979–85), though less pronounced than that in neighboring Gabon, had a clear urban bias. Public sector employment rose by two-thirds in just six years, and urban construction also increased. This accelerated rural–urban migration, which led to a slowdown in deforestation. In the crisis period, when the exchange rate was overvalued (1986–94), cash crops in the humid forest zone (mainly cocoa) were stagnant. But an upsurge in food-crop production caused a strong increase in deforestation in the forest zone.

The assessment of the shift in deforestation trends is highly reliable for Cameroon, because satellite imagery and agricultural survey data were collected for periods directly coinciding with the macroeconomic cycles. Research by CIFOR and its partners combined time-series satellite imagery with socioeconomic survey data on 5,000 households in 125 villages, generating primary data on both land use and rural household economies. In a block in Ndélélé, East Province, annual deforestation quadrupled between 1973–86 and 1986–96. In the Bertoua area in East Province, forest loss almost tripled, from 0.3 percent in 1973–86 to 0.8 percent in 1986–91. In the peri-urban area of Yaoundé forest, clearing doubled between 1973–88 and 1987–95.

Household survey data from villages in all three provinces of the humid forest zone confirm that forest clearing increased markedly after the onset of the crisis, as farmers increased their cultivation of food crops (Mertens and Lambin 2000; Sunderlin and others 2000). Reduced urban labor absorption and net return migration to rural areas were found to be key factors in the dramatic resurgence of deforestation.[8] Since the devaluation, cash crops have also experienced a slow revival, and deforestation continues to be high. Unlike in Gabon, oil wealth was not large enough to reverse forest loss and cause forest area to expand. The economic rents were not large enough to fully compensate for other factors, notably high rural population growth. But they caused an abrupt reduction in the pace of deforestation.

Cameroon thus provides a strong relative confirmation of the core hypothesis: During the oil-wealth period, the rate of forest loss dropped markedly.

Ecuador

The per capita size of the boom was larger in Ecuador than in Cameroon but much smaller than in Gabon and Venezuela. Due to rising production, oil revenues remained high until the mid-1980s. A bust followed, accompanied by a political crisis in the 1990s. Although there have been mini-oil bonanzas, the entire post-1985 period is best characterized as an economic downturn.

Nevertheless, deforestation actually accelerated during the oil boom, stayed high for a decade before likely decelerating. The government spent a large share of oil revenues in ways that promoted more extensive land uses. It built new and better roads connecting the highlands with the lowlands.[9] Fuel subsidies fostered extensification by making transport cheaper, though compared with roads, the effect of subsidies is nonspatial and reversible.[10] The government also used some oil money to support both spontaneous and planned frontier colonization that caused forest loss.[11] As in Venezuela, cattle were also a crucial factor, reinforcing the spatial extensification impacts of government policies. A growing urban middle class used part of its new purchasing power to buy cattle-derived proteins, thus creating higher demand matching the supply-side factors that enabled a large-scale expansion of pastures. Government trade policy partially protected meat and dairy products from import competition, allowing domestic producers to expand into marginal forestlands with meager returns.

In Ecuador these counterhypothetical factors were stronger than the core effect, and policy was decisive in creating that outcome. Dutch disease effects did reduce cropland expansion in the 1970s, and after the devaluations of the mid-1980s these reductions were reversed. But on the whole the forest eliminating pasture policy nexus was stronger.

Hence, the Ecuador country case study was contrary to the hypothesis in both absolute and relative terms. Forest cover decreased in absolute terms during the oil boom, and the pace of deforestation also picked up over the preboom period. This is indicated by both national forest cover data (with some comparability problems) and by agricultural area statistics, which are more reliable. The slowdown in deforestation in the 1990s, indicated by various regional forest data on hot spots of deforestation, may eventually be enhanced by the recent dollarization, which is likely to cause loss of competitiveness that will harm land-using sectors.

Papua New Guinea

Papua New Guinea became a specialized mineral exporter after 1972. Copper and gold predominated until 1992, when significant petroleum production began. The size of these mineral rents relative to the size of the economy was somewhat greater than in Ecuador. Firm macroeconomic management succeeded in controlling the impact of rents until the early 1990s, but since then fiscal control has been increasingly lost. The fixed kina exchange rate introduced in 1975 greatly hampered non-mineral exports until 1994, when a floating kina coupled with economic mismanagement led to a large real devaluation. In other words, there were fairly high mineral revenues throughout the whole period, but with different economic management cycles.

The most reliable land-use data, from the Papua New Guinea Resource Information System (PNGRIS) and covering the 1975–96 period, show that cash crops never became a significant cause of deforestation. Even after the kina devaluation, rural violence, inflexible land tenure arrangements, and infrastructure problems were large impediments. Thus in Papua New Guinea improved price competitiveness was not enough to induce expansion in the cash crop sector. An exception is the oil-palm sector, which caused some deforestation. As in Gabon, government policies tended to ignore rural infrastructure, which greatly reduced forest loss. A large share of mineral revenues went into consumption. Some mineral revenue was wasted, some was turned into capital flight, and little was invested to enhance production.

At the national level forest loss was clearly driven by swidden cultivation of food crops, the demand for which grew in tandem with the population. But the country's rigid land tenure structure, which strongly favored land intensification over extensification, was discouraging expansion into forestlands. Hence the increase in demand for land was much less than the increase in food crop production. Between 1975 and 1996 intensive land use expanded at 0.7 percent a year, but total land use increased by only 0.2 percent, far below rural population growth rates of around 2 percent (Allen and others 2001). Intensification is more labor-demanding than swidden cultivation in the forest fringes, but new forest clearing for swidden cultivation meets severe sociocultural constraints. Intensification is achieved by technically improving cultivation (terracing, improving drainage, composting, rotating crops, growing nitrogen-fixing fallow species), but also by introducing new crops or varieties (such as potatoes, sweet potatoes, and African yams; Bourke 2001).

Annual forest loss rates were 50,000–70,000 ha (about 0.2 percent). This is a low rate and was probably stable over time, though with respect to the small size of the population and the economy it was significant.[12] Few value-added and service sectors have developed that might have drawn people out of food crop agriculture and into urban activities to uncouple deforestation from population growth.

On the whole, mineral wealth in Papua New Guinea did not stop deforestation. It did slow forest loss, in particular by curtailing the production of cash crops. None of the other cases was as complex as that of Papua New Guinea. Factors such as land tenure, crime, and political instability were equally important in shaping land use.

Summarizing the Country Evidence

Developing economies are subject to long-run processes of structural change, such as demographic and economic growth, urbanization, shifts of resources from primary to secondary and tertiary sectors, changing consumption patterns, and expanding land use. The core hypothesis of the forest-protecting impact of mineral rents has to be evaluated against these normal development trends. Table 2 summarizes the

Table 2. Comparing Macroeconomic and Forest Cover Trends

Country	*Macroeconomic cycles*	*Forest cover change cycles*	*Main sources used to determine forest cover change*	*Evaluation of the core hypothesis*
Gabon	1960–73: Preboom; 1974–85: boom; 1986–89: mini-bust; 1990s: fluctuations	1970–1990s: Net forest regrowth; recent: Some periurban clearing, probably little net change	Remote sensing (two national maps,* peri-urban and village studies)	Absolute confirmation (short and long run)
Venezuela	1920/30s: rise of petro-economy; 1956–58: mini-boom; 1974–83: boom; 1984– : crisis and mini-booms	1920–50: forest regrowth; 1950–1980s: slow loss; 1980s–1990s: more rapid loss	National forest maps 1920, 1950, 1991;* regional forest maps; agricultural area data and estimations*	Absolute confirmation, before World War II; relative confirmation, after World War II
Cameroon	1960–78: preboom; 1979–85: boom; 1986–94: bust, fixed exchange rate; after 1995: devaluation, recovery	1973–85: slow loss; 1986–94: rapid loss; after 1994: probably high loss	Remote sensing images (national,* regional) and primary agriculture survey data from the humid forest zone	Relative confirmation
Ecuador	1960–73: preboom; 1974–81: boom (rising); 1982–85: boom (declining); 1986–95: bust; after 1996: mini-booms	Before 1975: moderate loss; 1975–90: rapid loss; 1990s: probably slower loss	National forest maps (1962, 1987, 2000*); regional forest maps; agricultural area data.	Rejection, absolute and relative
Papua New Guinea	1972–94: mineral boom (rising), fixed overvalued kina; after 1995: oil boom, financial capital outflows, devalued kina	Whole period: Probably stable, slow loss, linked to food-crop expansion; after 1994: Perhaps loss acceleration	National maps from aerial photos (1975) and satellite images (1992–93)*; PNGRIS land-use change database	Relative confirmation

Source: Wunder (2003b:chap. 10).
*Limitations in data comparability over time.

evidence for the five primary country case studies by juxtaposing their macroeconomic cycles and their land-use cycles.

Gabon and pre–World War II Venezuela are hypothesis-confirming cases in absolute terms. Large oil rents basically wiped out agriculture, and many abandoned areas grew back into forests. Forest cover increased in absolute terms. In Cameroon the oil effects were not strong enough to produce such an outcome. The boom was smaller than those in Venezuela and Gabon and thus could not nullify the forest-cover impact of rural population growth. But there was a clear relative reduction. The pace of deforestation decreased dramatically in the oil boom period and then picked up again during the crisis.

Papua New Guinea was also a case of relative confirmation, though a more uncertain one. Real exchange rate effects were mediated by shifts in economic policy, and several nonmineral factors had a crucial influence. Still, mineral wealth is one of the explanations for low deforestation rates. Finally, Ecuador was the only case that rejects the core hypothesis, mainly due to the policy of extensive road building and a nexus of factors that linked this expansion and land-extensive cattle ranching (including dairy farming) to oil wealth.

Tracing Linkages

The juxtaposition of periods in table 2 exhibits some (but not all) of the patterns one would expect for the core hypothesis. This is hardly surprising, given the long causal chain described in figure 1, the extended period of study, and the presence of country-specific peculiarities. The main transmission stages are from oil wealth to the real exchange rate and relative prices, from prices to sectoral production (agriculture and timber), and from sectoral production to forests. Detailed analysis of all these linkages for the study countries, including how to deal with various data problems related to deforestation and to macroeconomic variables, is available in Wunder (2003b). Some general comments on the strength of the linkages are presented here.

In most countries oil wealth produced the expected appreciation of the real exchange rate, with a shift in relative prices in favor of nontradables, though sometimes with a time lag (Wunder 2003b:chap. 10). For several countries, foreign borrowing was an integral feature of oil wealth. They often borrowed against their new oil wealth either to increase already high foreign exchange inflows or to prolong a boom period and so delay the downward adjustment in government expenditure linked to oil busts. Higher capital inflows from borrowing caused more real currency appreciation.

Management of nominal exchange rates also proved important. In the simple Dutch disease model currency devaluation has no impact on relative prices or competitiveness, because domestic prices adjust instantaneously so that the real exchange rate remains unchanged. In the reality of the case study countries, domestic prices were sticky, and overvalued exchange rates could persist for years. Hence, repeated devaluations (as in Ecuador and Indonesia in the mid-1980s) were vital in reviving traded sectors, whereas fixed exchange rate regimes exposed them to reduced competitiveness in other countries, notably in Cameroon and Papua New Guinea before 1994.

Agriculture was a prime victim of Dutch disease, but often it was the purely traded export sectors that were hardest hit by declining competitiveness. In Gabon and Venezuela appreciation of the exchange rate practically liquidated the cash crop export sectors. In Cameroon and Papua New Guinea it was probably the most important among several factors leading to economic crisis. The food crop sector was not always unambiguously hurt by appreciation of the real exchange rate. At the macro level food crops were semi-traded because of imperfect substitutes and partial trade protection over time, but also because of "natural" protection from trade provided by the high costs of transport to remote or inaccessible regions. To the extent that semi-traded goods were strongly linked to higher income (meat, dairy products, luxury staples), domestic suppliers profited from higher demand, as was the case with producers of nontraded goods. To the extent that semi-traded goods were close substitutes for importables and had low income elasticities (such as tubers and plantains), producers lost market shares, similar to those in traded sectors.

Did effects on agricultural production translate directly into forest impacts? As explained, forests were the default vegetation cover in most regions, so higher demand for land would in most cases cause corresponding loss of forests. However, the linkage of higher agricultural production with higher demand for land could be somewhat variable. In Papua New Guinea lack of physical access and legal rights to new land promoted intensification on already occupied soils, so that land demand increased less than production. The opposite was the case for cattle ranching. In both Ecuador and Venezuela the aggregate cattle carrying capacity declined over time, reflecting the spread of ranching to still more marginal lands with lower per hectare returns.

Still, in all the case study countries agriculture was the big land-use competitor with forests. Gains for agriculture meant losses for forests. The somewhat uneasy implication is that most of what is good news for agriculture tends to be bad news for forests, and vice versa. As the next section shows, this also means that policies that are biased against agriculture may, unintentionally, be forest conserving—and more effectively so than policies aimed directly at forest conservation.

Decisive Policy Responses

The country analysis shows that the net impact of oil wealth on forests is often to enhance forest protection, as predicted by the core hypothesis. Yet specific case study outcomes ranged from absolute confirmation to relative confirmation and, in one case, to rejection.[13] Country-specific preconditions were in part responsible for the variability of outcomes. For instance, large oil booms are conducive to forest protection, but in Latin America a meat and cattle tradition in the region exerted significant pressures on forests when incomes rose. In Central Africa and Papua New Guinea deforestation is mainly for land-extensive swidden cultivation, though in Papua New Guinea there was a strong intensification response.

Yet beyond these preconditions, distinct country-specific policy responses strongly shaped the variation in outcomes. Governments were not passively reacting to the changing fortunes of the world market or, as some claim, simply adopting adjustment programs designed by the Bretton Woods institutions. On the contrary, the rent-rich oil states developed an ability to steer clear of external pressures and influences, delaying adjustment and resisting cutbacks and reforms. Internally, they were also able to buy off powerful stakeholder groups, though this came at the cost of increased rent-seeking and corruption. In some cases oil wealth in itself was conducive to armed conflict with separatist movements trying to appropriate the rich natural resources (Collier 2000; Ross 2001; Wunder 2003b:chap. 10). In the aggregate it is fair to say that the oil-rich countries had greater room for political maneuver than most developing economies and that they used this political space in ways that had important consequences for forests.

Which policies, then, proved most effective in protecting forests, regardless of whether there was any intent to protect them? Experience in Gabon, where long-run land-use determinants have favored conservation, can be combined with policy ingredients from other study countries to create a list of factors that have tended to result in forest conservation (table 3). This is not a list of policy recommendations—few of these policies are propoor development policies. It is simply a list of policies that de facto have protected forests in the case study countries.

Conclusion and Perspectives

This study supports the core hypothesis that oil and other mineral wealth tends to protect forests (though not in all cases) through indirect, economywide effects that discourage land- or forest-based commodity production and reduce their competitiveness. This macroeconomic impact of mineral rents on forests is bound to be more significant than the direct, physical effects of mineral production in forested areas. Most of the countries studied conformed to the core hypothesis in relative terms (oil wealth *reduces* pressures that degrade and convert forests), some even in absolute terms (oil wealth *reverses* pressures that degrade and convert forests), and only one (Ecuador) of the primary case study countries was *contrary* to the hypothesis. The absolute conformers (Gabon, pre–World War II Venezuela) had high oil rents per capita. The only negative

Table 3. Policies in Case Study Countries That Inadvertently Resulted in Forest Conservation

Policy	*Comments*
Neglecting demands for new road building and road maintenance in rural areas.	Countries with large road-building programs had high deforestation rates (Ecuador, Indonesia) and those neglecting rural roads had low deforestation rates (Gabon, Papua New Guinea). This macro-level observation confirmed micro results strongly tying roads to forest loss.
Selling fuel domestically at its "normal," nonsubsidized price.	This policy is forest-conserving. Conversely, selling cheap, subsidized fuel reduces transport costs for goods (crops, livestock, wood products) from remote areas and thus promotes land extensification. This had an impact especially in countries where the fuel subsidies reached extreme levels, as in Venezuela.
Spending large amounts of funds on cities.	A strong urban development bias, such as that seen in Gabon, protected forests, by attracting labor migration out of rural areas. Conversely, spending on social infrastructure in forested frontiers eventually helps attract migrants, sustain settlement, and promote forest conversion to alternative uses.
Keeping overvalued exchange rates.	Most nontraded sectors are urban, so overvalued exchange rates helped sustain urban biases and jeopardized cash crop production. On the other hand, sharp, repeated currency devaluations were a powerful tool to make agriculture and timber extraction more competitive.
Overtaxing export agriculture by confiscatory price stabilization schemes.	Commodity funds that de facto transferred cash crop earnings from farmers to the government or to an administrative bureaucracy impeded a larger scale expansion of cash crops, especially in the African case study countries, which in most cases would have caused additional deforestation.
Heavily taxing logging companies to capture stumpage values.	In Papua New Guinea in the 1990s, a sharp rise in taxes reduced the speed of harvesting. However, if logging concessions are overly generous (in the sense of low taxes), as occurred for certain periods in Cameroon, Indonesia, and Venezuela, companies rush to cash in high timber rents, and this tends to accelerate forest conversion.
Intensifying food production and liberalizing food imports.	The net impact of general trade liberalization on forests is ambiguous, but import protection of cattle and certain land-extensive (typically, swidden) food-crop sectors helped these sectors expand production into marginal forestlands with very low per hectare returns.

(Continued)

Table 3. (Continued)

Policy	*Comments*
Forcing rural people to settle in concentrated roadside agglomerations.	Many colonial and postcolonial settlement programs, especially in Central Africa, concentrated swidden cultivators in sedentary roadside settlements with more land-intensive methods, thus reducing forests clearing. Conversely, an Indonesian-style *transmigrasi* resettlement of people without land to a (forest) land without (a lot of) people causes deforestation.
Wasting agricultural budgets on agro-industrial "white elephants" and ignoring smallholders.	Oil-financed modernization strategies to promote sedentary, capital-intensive cropping tended to require less land per unit of value added than traditional farming. Yet much funding for agro-industry was diverted or wasted, so lack of agricultural development meant avoided forest loss.
Nourishing a rent-seeking environment in which few people find it worthwhile to produce.	In high-rent oil countries personal income is increasingly divorced from production and determined instead by the success of rent-seeking efforts. This has reinforced urban biases and has provided disincentives for commodity production—further relieving pressures on forests.

Source: Author's compilation.

secondary case was Mexico, and as in Ecuador (and recently in Venezuela), a Latin American roads–colonization–cattle nexus drove the counterhypothetical outcome.

Deforestation data for all study countries are poor and involve much guesswork, but agricultural census and land-use survey data can sometimes compensate for this lack of reliable information. This is because in all study countries conversion to agricultural land (including pastures, fallows, and degraded croplands) was the dominant ultimate use of cleared forestland. Forests receded basically because people decided to cultivate tree-covered lands. Within agriculture, production and land used for "purely traded" export crops was clearly held back by oil-led Dutch disease effects on competitiveness. For semi-traded food crop sectors, trends were ambiguous, but in most cases land expansion was also constrained by rising wages and urban migration, which were especially important when these crops were produced in swidden, land-extensive systems. Cattle ranching was often linked procyclically to oil wealth through import protection and a high income elasticity of consumption for cattle-derived, protein-rich foods. In regions where this cattle effect was dominant (Latin America), the core hypothesis was less likely to hold than in others (Central Africa, Papua New Guinea) where the reduced expansion of land-extensive crops was the dominant force. This underscores regional peculiarities in the relation between higher national income and forest loss.

Did governments have an important say in how oil wealth affected forests? They certainly did, even though these influences were unintentional. Governments normally are the sole custodians of a country's mineral riches.[14] An urban bias in the spending of oil revenues (increased public employment and urban investments) would generally protect forests, whereas spending on new and better rural roads, infrastructure in frontier areas, and (especially) agricultural and fuel subsidies counteracted the core forest-protecting impact. Notably, expansions or cuts in the budgets of government forestry and conservation agencies—sometimes observed to be a key environmental factor in crisis-ridden countries (Reed 1996; Sunderlin and Rodríguez 1996)—had little effect. In most case study countries the implementation capacity of these agencies was low, irrespective of the level of resources available (see also Kaimowitz and others 1998). In addition to spending decisions on oil wealth, several policies significantly influenced the use of land and forests, notably exchange rate policy, import protection of selected sectors, and forestry concession policies.

The list of 10 forest-protecting policies in table 3 invites two general observations. First, only one of the factors—taxing logging concessions—affects forests directly. All the other measures are outside the sector, side effects of policies not targeted at forests—what could be called "blind conservation strategies." This underscores the crucial importance of understanding the underlying causes of deforestation.

Second, the list is somewhat pessimistic in that most of these inadvertent conservation policies are not conducive to economic growth or poverty alleviation. Many are directly harmful. Compared with a standard of best practice development policies, arguably only 3 of the 10 policies—elimination of fuel subsidies, high taxes on logging stumpage value, and intensification and import liberalization of resource-wasteful sectors—would receive a positive evaluation. This indicates that the hard tradeoffs between tropical forest conservation and economic development occur not only at the micro level but also at the macro policy level. On the other hand, the list identifies three tangible areas in which positive synergies may be present.

Implications beyond Oil

The policy results reported in the last section may be provocative and raise legitimate questions about whether, first, the chosen countries are representative of oil countries and, second, to what extent results from oil-producing countries in tropical areas are applicable to developing economies that are not endowed with oil. On the first question, the five primary case study countries represent a fairly broad mixture of developing countries in terms of geography, gross domestic product level, agricultural traditions, and ecological conditions. Perhaps they inadequately represent dry forest countries, where firewood overharvesting and overgrazing can be causes of deforestation. They are also all small to medium-size economies, which is why the analysis was eventually supplemented with three big-country cases from each southern continent: Mexico, Nigeria, and Indonesia. Nigeria and Indonesia were cases of relative confirmation of the core hypothesis (deforestation rates dropped during the oil boom but did not turn negative), whereas Mexico was a case of rejection.

The second question is harder to answer. Developing economies specializing in oil production are on average richer, more urbanized, more high-cost, and less agricultural than other developing economies (Sunderlin and Wunder 2000). In the political economy sphere, many oil countries suffer from "resource curse" problems of underinvestment in human capital, ill governance, rent-seeking, institutional decline, and economic stagnation. These features definitely make them a special sample. For instance, rent-seeking and corruption related to illegal logging are known to cause severe forest degradation. However, in our group of countries, the fact that rent-seeking was happening in the urban sectors and that corruption was connected with agro-industrial programs meant that corruption came to have a forest-protecting effect, something that is obviously not fully generalizable to other countries.

Still, many of the macroeconomic phenomena and policies analyzed here are equally common in nonoil-producing countries. Perhaps the main differences in terms of policy responses is that in nonoil-producing countries a wider range of private sector activities would be expected (with differential impacts on forests), in particular a higher diversity of agricultural scenarios with different land-use intensities, as well as stronger production responses. However, there is no reason to believe a priori that nonoil-producing countries would systematically face either weaker or stronger forest protection effects from a substantial foreign exchange transfer from abroad.

Do these findings have implications for countries that are not blessed with mineral wealth? As suggested by the wide applicability of the Dutch disease model, the impact of a mineral boom's spending effect is similar to that of other international rent transfers, such as remittances, foreign aid, and debt relief. All of these foreign exchange inflows tend to increase aggregate demand, cause real currency appreciation, and speed urbanization. A large-scale global reduction or write off of foreign debt under the Heavily Indebted Poor Countries Debt Initiative, for example, would, on the whole, also lead to less tropical deforestation. However, the deviating case studies show that this effect would not be guaranteed in every country. Hypothetically, the forest protecting effect of debt reduction would be expected to be stronger in a poor African country dominated by swidden cultivation than in a middle-income Latin American country where most forest clearing is for pasture. In the Latin America case rising incomes for an urban middle class with a large appetite for meat can increase forest loss.

A second field of application concerns the claim that structural adjustment programs have strong negative effects on forests and the environment and thus need to be environmentally screened and redesigned (Reed 1992, 1996). Counterarguments have been that many environmental effects are unavoidable or too complex to analyze or that there are internal contradictions among different environmental objectives. This study confirms that many actions to improve foreign exchange inflows by revitalizing traded sectors will almost inevitably have negative impacts on forests. In particular, it confirms the powerful role of currency devaluation, a key policy tool in most structural adjustment programs in promoting land- and forest-using sectors. Our study gives less support to the assertion that specific fiscal cutbacks in forest regulating agencies have detrimental effects (see previous discussion). Instead, it points to the danger that sharp general declines in public spending can partially "reruralize" the economy at the expense of forests.

Finally, trade liberalization and export incentives have been singled out as highly ecologically damaging components of structural adjustment programs. The results of this study suggest that the argument is often valid but that import liberalization can also restrict highly wasteful and forest-damaging domestic sectors, thus increasing the natural resource efficiency of land uses to the benefit of forests. For instance, it may well be preferable to fill the barbecue of an Ecuadorian family with meat from the Argentine pampas, rather than from deforested erosion-prone and nutrient-poor slopes in the Ecuadorian Andes. Likewise, it might well be better for global forest conservation if a Central African urban family builds its staple diet on imported Thai high-yield variety rice rather than on local plantains, whose production requires reiterative burning of extensive peri-urban forest plots. The net balance of trade impacts on forests will differ across countries, and the impact on forests will differ from that on other environmental assets. This underscores that asset- and country-specific assessments of structural adjustment effects are necessary, reducing the scope for generalization. However, this study also shows that, despite the complexities, it is possible to analyze these effects. This should also serve as an encouragement to those interested in modifying macroeconomic tools for the purpose of improving environmental outcomes.

Notes

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1. If Brazil, now a low mineral exporter but endowed at the state level with important mineral exports, is excluded from the denominator, that share rises to 72.1 percent (Wunder 2003b:chap. 2).

2. Caracas is said to grow at the rate of about 1 ha a day, yet the additional land demand of 365 ha a year corresponds to only 0.09–0.15 percent of Venezuela's forest loss. In Greater Jakarta, one of the world's fastest-growing metropolitan areas, forests receded from 73,266 ha in 1969 to 43,691 ha in

1989, yet the annual clearing of about 2,000 ha contributed only 0.1–0.3 percent to Indonesia's deforestation (Prasetyo 1992).

3. The highest level of analysis in this study is the nation-state, so this article does not look at the global consequences of oil wealth and of changed international trade patterns.

4. Sunderlin and Wunder (2000:318–20) demonstrate, using comparative data for 66 countries, that high urbanization in a subset of mineral-rich countries is one of the structural characteristics related to a higher share of forest cover and a lower rate of forest loss.

5. Most sources are from the early 1990s. TREES data from 1991–95 are used as a benchmark. IUCN data are from the latest available nationwide map (various years), whereas the *Forest Resources Assessment 2000*'s 1990 estimate (FAO 2001) is calculated backward to its 1990 base.

6. This section summarizes the main lessons from chapters 4–8 in Wunder (2003b).

7. Chief Mboula Thaopile, Nioungou village, cited in Adams and McShane (1996:207).

8. Demographic surveys showed that average annual population growth exploded from 0.75 percent in 1976–86 to 4.6 percent in 1987–97. During the boom period the urban economy had absorbed most of the rural population surplus. In 1986–92 rural to urban migration stagnated, and as the crisis continued (after 1992), there was net urban–rural return migration (Sunderlin and Pokam 2002).

9. In 1974, the first full oil boom year, Ecuador spent 48.4 percent of public investments on roads (Gelb and Marshall-Silva 1988:184). Many roads were built through forests, causing immediate deforestation as well as continuing deforestation for about a decade following completion of the roads (Pichón 1997; Rudel and Horowitz 1993; Wunder 2000).

10. As in Venezuela, massive fuel subsidies in Ecuador were politically difficult to reverse after the boom, and in 1986 their cost reached an astonishing 9 percent of gross domestic product (Mosley 1991:414). Together with the new roads, subsidies drastically increased the mobility of goods and production factors in the rural economy. Although only about 20 percent of peasant production was marketed in the 1960s, 60 percent was in the 1970s (Larrea 1992:350–51).

11. Development banks specialized in cattle, the most extensive form of land conversion, and expanded their credit volumes thanks to earmarked oil revenues. Several regional and national land colonization institutes received oil money that had been earmarked by the government for agricultural development (Rudel and Horowitz 1993, pp. 56–7; Wunder 2003b, pp. 237–8).

12. Data from PNGRIS need to be translated first to obtain deforestation information defined according to FAO standards. There have probably been few fluctuations over time. For example, the increase in logging triggered comparatively little additional forest clearing. But with Papua New Guinea's small population of 4.7 million (1999), a point estimate of 60,000 ha is larger on a per capita deforestation basis, at 12.8 ha/1,000 people, than Ecuador's (12.1) and Cameroon's (11.9) (Wunder 2003b:chaps. 8, 10).

13. Among the three secondary cases—Indonesia, Nigeria, and Mexico—the first two were probably cases of relative confirmation. Forest loss was not reversed, but was weakened during oil boom periods. As in other cases, cash crop production declined precipitously, while food crops were semi-traded with an intermediate production performance. The same happened in Mexico, but as in Ecuador and Venezuela, the Latin American nexus of road building–colonization programs–cattle meant that Mexico contradicted the core hypothesis. There was procyclical deforestation for pasture creation, although evidence was also found at the subnational level (Chiapas state) that supported the hypothesis.

14. A partial exception here was Papua New Guinea, where both regional governments and local landowners directly received a nontrivial share of oil and mining revenues.

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