AN ECONOMETRIC ANALYSIS OF THE CAUSES OF TROPICAL DEFORESTATION: GHANA

by

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Short Abstract

Deforestation is modeled in two stages, as an interaction of interlinked key sectors in the Ghanaian economy (including forest products exports, fuelwood energy consumption, cocoa production, and food crop production), which compete for forest landuse or forest products. The effects of the different first- and second-level causes of deforestation analyzed are discussed.

Keywords: Two-stage regression, elasticity of deforestation, forest policy/management.

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Introduction

Forest resources in Ghana are being depleted at a faster rate compared to other developing tropical countries. Since 1981, average annual rate of deforestation in Ghana is estimated at 2.0%, compared to 0.9% for all tropical forests, 0.6% for Zaire, and 0.6% for Brazil (World Resources Institute). The efforts of successive governments to reduce deforestation have yielded only limited success, primarily because many of the initiatives were misguided and/or failed to deal with deforestation as a complex, dynamic and interlinked process.

Forest resource management requires inter-linked and multi-sectoral policies, rather than policies targeted at the forestry sector alone (Saxena, Nautiyal and Foot). Deforestation in Ghana is affected by government policies both within and outside the forestry industry, especially the agricultural and energy sectors. Thus, policies aimed at minimizing deforestation must be based on a sound understanding of the complex and dynamic interrelationships between the various levels of causal factors.

Previous forestry studies for Ghana (e.g., Dei, 1990; 1992; Townson) involved largely rudimentary qualitative research and focused primarily on community-specific ethnobotanical and anthropological issues (an exception is Owusu) who examined the effect of the structural adjustment program on the forest sector). Although economic studies for other regions have identified various factors which affect deforestation, the interplay of the inter-relationships among the causes depend on the country, and make policy prescriptions for other regions inappropriate for ameliorating deforestation in Ghana. Yet, there is no previous published economic study of the factors affecting

deforestation in Ghana. Given that forests are economic resources (because forest resources help produce goods and services that are consumed), forests must be managed and used based on economic considerations (Pearse). In addition, economic decisions should undergird national policy choices and decisions in sustainable forestry management (Arnold).

This study used econometric methods to analyze the complex relationships between deforestation and its hypothesised causes in Ghana. A two-stage regression analysis was conducted, where the causes of deforestation were grouped into first-level, direct causes and second-level (or indirect) causes. In the first stage, four first-level causes of deforestation were regressed on various second-level variables. In the second stage, deforestation is regressed on the estimated first-level causes of deforestation. A second objective of this study was to evaluate the possible policy interventions, and provide insights especially on how limited resources could be prioritized in managing Ghana's forest resources, based on the elasticity of deforestation with respect to the various direct and indirect causes.

Deforestation Model

To capture the complex interactions and inter-relationships associated with deforestation, we adapted the Kant and Redantz multi-level framework in which the key factors which influence deforestation rate were divided into first-level (direct) and second-level (indirect) variables. The effects of the direct causes are determined by a complex interaction of various second-level (underlying) causes and, therefore, are endogenous to the system. It was hypothesized that there are four direct causes of

deforestation in Ghana, consisting of geophysical and biophysical variables.

Deforestation studies for other countries have explicitly analyzed livestock sector grazing effects in removing forest biomass and in forest regeneration (e.g., Saxena, Nautiyal and Foot). Unfavorable climate and, in particular, the prevalence of trypanosomosis transmitted by the tsetse fly has resulted in very limited livestock production in the forest region of Ghana. On the other hand, other subsectors within the agricultural industry, particularly food crops and cocoa production, are the dominant agricultural activities in the forest zone and better reflect forest degradation than livestock grazing effects.

A deforestation model was estimated using a system of five recursive regression equations. Equation 1 describes the relationship between the amount of deforestation Z_1, and the various direct causes as independent variables:

$$Z_1 = \alpha_1 + \beta'_1 Y_1 + \varepsilon_1 \qquad (1)$$

where Z_1 is annual deforestation, Y_1 is a vector of first-level causal factors, including forest products exports, fuelwood consumption, cocoa production, and food crop production. α_1 is the intercept term, β'_1 is a row vector of coefficients associated with the four explanatory variables, and ε_1 is the error term. Details of the first- and second-level causal factors are discussed in the following sections, along with an assessment of their link to deforestation.

Forest Products Exported

Exports of forest products is the third leading source of foreign exchange in Ghana and plays a key role in deforestation. Although the volume of traditional forest products exported have declined over time from levels obtained during the 1960s, actual

value of products from forests has been increasing due largely to value-added activities and, more recently, to an increasing emphasis on nontraditional timber and non-timber forest products exports.

Commercial timber harvesting, by itself, may not necessarily lead to deforestation. However, by opening up forests, farmers and other encroachers find it easier to further exploit the forest resources. Arnold reported that the high incidence of Ghanaian women's involvement in non-timber forest product activities is largely due to the easy access to forest resources, uncovered by commercial timber merchants. Given the inadequate protection of forests by the Ghana Forest Service, and the limited forest management and reforestation activities, commercial logging directly leads to deforestation. Thus, volume of forest products exports was hypothesized to be a first-level factor, and aggravates deforestation.

Forest products exports was hypothesized to be inversely correlated with national income, and positively correlated with the size of Ghana's external debt. GDP was used as a proxy for national income in the absence of a more appropriate dataset for national income, such as transitory real disposable income (Kant and Redantz). There are contrasting findings on the effect of forest product prices on forest product exports and, ultimately on deforestation. Economic theory suggests a positive correlation between forest products exported and export price of wood products received by exporters. On the other hand, low timber prices discourage efficient harvesting and processing, thereby resulting in more logging and, ultimately, increases timber exports (Barbier, et al.). Given that data on prices for each forest product exported was not available, export price for a

composite (wood products) commodity was derived as the total value of exports divided by the quantity exported.

A final variable included in the forest products exports model is Ghana's comparative advantage in forest resource endowments. Total forest area was used as a proxy for comparative advantage, since the majority of exports from Ghana are land-based primary commodities (Kant and Redantz). Comparative advantage on forest products was measured in terms of forest area as a percentage of total land area.

The forest products exported equation can be represented as:

$$Y_2 = \boldsymbol{d}_2 + \boldsymbol{g}'_2 X_2 + \boldsymbol{e}_2 \qquad (2)$$

where Y_2 represents annual exports of forest products, X_2 is a vector of explanatory variables including GDP, export price of forest products, total external debt, and forest area as a percentage of total land area. δ_2 represents the intercept term, γ'_2 is a vector of coefficients on the regressors, and ε_2 the error term.

Fuelwood Consumption

Fuelwood and charcoal energy consumption is one of the major causes of deforestation (Allen and Barnes; Charkraborty). Forest biomass removal for fuelwood and charcoal represents the main source of energy for over 75% of Ghana's population (FAO, 1995). Fuelwood energy is used not only for domestic cooking and heating, but is also widely used in small-scale industries (such as local breweries, bakeries, soap making, and fish processing). Forest biomass removal for fuelwood is both a cause of deforestation as well as a consequence of the socio-economic structure of the Ghanaian society; reflecting an interaction of factors such as economic wellbeing, population pressure, and settlement structure (Saxena, Nautiyal and Foot). In the transitional and

northern savannah zones where little commercial logging takes place, fuelwood and charcoal production play a major role in forest loss. To minimize the heavy dependence on fuelwood and charcoal energy, the government of Ghana introduced and encouraged the use of liquefied petroleum gas (LPG) for cooking and heating during the 1980's. Thus, the relative importance of forests in providing energy makes fuelwood consumption an important factor to investigate.

Economic theory suggests that aggregate national consumption of fuelwood depends on national income and price of the good, among other factors. Kant and Redantz used GDP as a proxy for national income, in the absence of a more suitable variable such as transitory real disposable income. Although consumer theory suggests a positive correlation between income level and quantity of a (normal) good purchased, the role of income (or its proxy) on fuelwood consumption could be ambiguous. Higher income levels can result in a shift from using wood-based energy to alternative energy sources such as LPG and electric stoves, thereby reducing fuelwood consumption and, ultimately, minimizing deforestation.

The lack of a suitable price variable for fuelwood and charcoal was mitigated by Kant and Redantz, who argued that individuals perceive a forest as a free common good because of its vast and unbounded nature. Such free common good attitude (FCGA) reflects individuals' perception about the extent of forest area, which in turn depends on the actual forest area (and public policies). A stronger FCGA increases fuelwood consumption. Thus, FCGA (i.e. total forest area) was used as a proxy for the price variable. Other studies besides Kant and Redantz (1997) which used total forest area include Kahn and McDonald, and Rudel.

Arnold reported that market demand for wood fuels is associated with growing urban populations, but also noted that most forest products used locally are typically bought by low income rural consumers. Townson's evidence that forest products were bought by both rural and urban populations suggests that various population variables could affect deforestation in different ways. Consequently, several population variables (including total population, agricultural population, and rural population) were tested in different versions of the fuelwood consumption model. A time index was also included to capture the effect of technology. A final variable included in the fuelwood consumption equation reflects the state's capacity to enforce forest and woodland protection, and general property rights on natural resource management. PRORIGHTS was a dummy variable, equal to 1 for periods when there was a constitutional government and 0 for military regimes. Thus, the fuelwood consumption equation is represented as:

$$Y_3 = \delta_3 + \gamma'_3 X_3 + \varepsilon_3 \qquad (3)$$

where Y_3 is the annual fuelwood consumption in tonnes, X_3 is a vector of GDP, population pressure, absolute forest area, property rights on resource use, and time index. δ_3 represents the intercept term, γ'_3 is a row vector of regression coefficients, and ε_3 is an error term.

Cocoa Production

Cocoa is the primary agricultural export commodity for Ghana and is currently the second leading source of foreign exchange. Diversification of exports through increasing emphasis in nontraditional exports has also resulted in substantial expansion in processed cocoa products such as cocoa butter, cocoa liquor, and cocoa cake. Partly because of its relative contribution to the economy, and for most practical purposes, the

cocoa subsector is usually officially managed as a separate unit from the rest of the agricultural sector. Consequently, a model of deforestation was developed to reflect this special role of cocoa production within the agricultural industry.

Although cocoa can be grown under cultivated tree crops, Ghanaian farmers usually cultivate it under (natural) forest shade trees. Farmers prepare new cocoa land by clearing undergrowth in forests or by acquiring land that has been (partially) logged by timber merchants. In this study, annual cocoa production rather than area planted to cocoa is tested as a direct cause of deforestation because area planted sometimes includes encroached upon forest reserves, which are usually treated in forestry inventories as intact forest reserve areas. In addition, some satellite images of forest areas typically indicate little distinction between forest cover and tree cover beneath which cocoa is cultivated. The factors which influence cocoa production, and which are linked to deforestation, were hypothesized to include producer price of cocoa, total external debt, population pressure, growth rate of GDP, absolute forest cover, cocoa production index, and the strength of public institutions charged with preventing encroachment into forest reserves.

The cocoa subsector supports the economy in terms of its contribution to GDP, employment, and export and fiscal revenue. Growth rate of GDP is therefore a key determinant of cocoa production. External debt is one of the most discussed explanatory variables of deforestation and is hypothesized in this study to work through trade in cocoa products. In countries with substantial external debt such as Ghana, growing total debt can affect the tendency to produce and export more cocoa (Caspistrano).

A large absolute forest area also presents an incentive for deforestation (Kant and Redantz): the larger the forest area, the more likely cocoa farmers will consider forest as

a free good for increased cocoa production and legally expand area cultivated or encroach upon it. There are contrasting findings on the effect of crop productivity index on crop production and on deforestation. A negative relationship between agricultural productivity and relative forest cover (Katila), reflects the behaviour of commercial operators who produce for the export market and are motivated by high crop productivity to expand cocoa production, thereby deteriorating forests (Lombardini). On the other hand, Reis and Guzman found that agricultural productivity had a significant and positive effect on deforestation, in line with the expected behaviour of subsistent farmers and the environmental Kuznetz curve literature (Stern, Common and Barbier). Higher incomes (from higher crop productivity) beyond certain income levels reduce the need for additional income and therefore negatively affect further production, with declining effects on deforestation. In other words, the higher the productivity, the lower the land area that is cultivated for the same output level and hence the lower the effect on deforestation. The cocoa production index variable analyzed was measured in terms of yield of cocoa per unit area cultivated.

In Ghana both officially delineated and undemarcated forest reserves have been subjected to encroachment, illegal logging, and charcoal-making, partly because regulations and laws on forest sector administration and management are outdated and/or not adapted to their tasks. Several studies also emphasize the role of political stability and well-established rule of law in managing and conserving forests (e.g., Deacon,1996; Thirgood). Insecurity accompanying revolutions and military insurrections that destabilize established governments reduce conservation motives to minimal levels and therefore reduce forest cover (Deacon, 1996). Thirgood's assessment of the

Mediterranean region also found a clear relationship between the security that accompanies stable governments and good land stewardship. A proxy for the strength of public institutions, established rule of law, and respect for property rights was tested in terms of whether the country was under a constitutional rule or military dictatorship. The cocoa production equation is therefore represented as:

$$Y_4 = \delta_4 + \gamma'_4 X_4 + \varepsilon_4 \qquad (4)$$

where Y_4 represents annual cocoa production, X_4 is a vector of producer price of cocoa, total external debt, growth rate of GDP, absolute forest cover, cocoa production index, and state capacity to enforce forest protection. δ_4 is the intercept term, γ_4 is a row vector of coefficients associated with the independent variables, and ε_4 is the error term.

Food Crop Production

Subsistent and commercial food crop production provide food supplies for the growing population. The rate of clearing new croplands by shifting cultivators and permanent crop operators tend to be higher in relatively low agricultural productivity countries (Allen and Barnes). The agricultural sector as a whole provides employment to over 70% of the Ghanaian population, many of who are engaged in food crop production. Growing scarcity of, and the need for more fertile cropland in Ghana has caused expansion of food cropland into forest areas.

Key determinants of cropland expansion into forest areas include population pressure, and rate of growth of GDP (Angelsen and Kaimowitz). Increasing population pressure on existing croplands prompt farmers (especially from the three northern regions) to migrate to forest areas and resort to shifting (slash and burn) cultivation. Thus, increasing population ultimately lead to increasing conversion of forest to

cropland. The logic and assumptions associated with rate of growth of GDP is similar to its effects in forest products exports, discussed earlier.

Although food crop production index itself is a key independent variable that influences variations in cropland (Kantz and Redantz), extended time series on yields and on cropland for Ghana are not reliable. In addition, one of the two (i.e. yield and area cultivated) is typically calculated as a function of the other. Consequently, this tends to impose an upward bias on the relationship between area and crop output, thereby impairing part of the explanatory power (Angelsen and Kaimowitz). Under such conditions, an agricultural production index is a better independent variable (Kant and Redantz).

The strength of public institutions responsible for preventing encroachment into forest reserves, and farm-steading property rights regime affect claims to future land rents and, hence, give farmers an added incentive to clear forest land. Frequent conflicts between government organizations and communities also prompt users to compete for forest land. As in the forest product exports equation, a proxy for the strength of public institutions and property rights associated with forest land use was a dummy variable reflecting whether the country was under a constitutional or military regime. The crop production equation is given as:

$$Y_5 = \delta_5 + \gamma'_5 X_5 + \varepsilon_5 \qquad (5)$$

where Y_5 represents annual food crop production, X_5 is a vector of growth rate of GDP, population pressure, absolute forest cover, food crop production index, and the strength of institutions charged with preventing encroachment into forest reserves. δ_5 denotes the intercept term, γ'_5 is a row vector of regression coefficients, and ε_5 is the error term.

Study Methods

The datasets were first tested for (non)stationary by determining whether the nonstationarity is due to deterministic time trend or unit roots, using the augmented Dickey-Fuller test. Four of the variables studied were integrated of order one I(1), but we could not reject the null hypothesis of no cointegration. Consequently, these four variables were transformed to ensure that stochastic properties are invariant with respect to time, by using their first difference forms in the analysis, along with the remaining variables found to be stationary. Autocorrelation problems were further corrected using a modified Cochrane-Orcutt procedure involving iterative maximum likelihood estimation (MLE), for all five equations (White).

Data

The data used in the analysis are from FAO (2000) and from World Bank (various issues) statistical reports. Data on agricultural productivity, landuse, and population were taken from FAO (2000). The FAO (2000) defines forest and woodland area as land under natural or planted trees, regardless of whether it is intended for harvesting or not. Deforestation is therefore defined in this study as the average annual reduction in forest and woodland area. Information on GDP, external debt and other socio-economic variables were taken from World Bank (various years). The equations were estimated using time series datasets from 1961 to 1999. Details of the variables analysed and the units of measurement are described in Table 1.

Deforestation analysts face a unique problem regarding reliability of datasets (Jantz). Rudel and Roper noted that even the FAO Tropical Forest Resources

Table 1. Description of Variables Used in the Regression Analysis

Sector/Variable	Description	Units
a) Forestry Sector		
DEFOR	Average annual change in forest area and woodland (deforestation)	Hectares
FORAREA	Absolute forest and woodland area	'000 hectares
FORAREA%	Percentage of total land area of Ghana covered by forests and woodlands	Percent
CFWCON	Annual change in consumption of firewood and charcoal (fuelwood)	Cubic metres
FORPEXP	Export of forest products	Cubic metres
b) Agricultural Sector		
COCOPROD	Cocoa production	Tonnes
CFOODPROD	Annual change in food crop production (all food crops combined)	Tonnes
COCOPRICE	Producer price of cocoa received by farmers	Cedis per metric tonne
CROPINDEX	Index of agricultural production (excluding cocoa)	Base year 1987
COCOAPINDEX	Index of cocoa production	Base year 1987
c) Macroeconomic Sector		
GDP	Nominal total Gross Domestic Product (GDP)	Million US $
GDPGROWTH	Annual growth rate in GDP	Percent
EXTDEBT	Total external debt	Million US $
EXPRICE	Price per cubic meter of forest products exported	US $ per m^3
d) Demographic		
CTOTALPOP	Annual change in total population of Ghana	Thousands
CAGRICPOP	Annual change in population engaged in agricultural production	Thousands
e) Other		
PROPRIGHTS	A dummy variable for state capacity to enforce forest protection and property rights	Equals 1 (0) for periods when there was a constitutional (military) government

Assessment dataset, arguably the best available data source (Jantz), are questionable. This study used the most recent data sources and the best available published data. Nevertheless, the results should be interpreted and used with caution.

Results and Discussion

Most of the coefficients had the expected signs and were significantly different from zero. A summary of the regression results for all five equations are presented in Tables 2 and 3, including standardized coefficients and elasticities. Standardized coefficients measure changes in individual dependent variables (in terms of standard deviation) with respect to a change in the independent variable (in terms of standard deviation). In contrast, elasticities measure the percentage change in a dependent variable with respect to a unit percentage change in a given independent variable. Although in practice measures of elasticities are more useful than standardized coefficients, consistent ranking by the two measures for a set of explanatory variables provides increased confidence in interpreting the findings.

Forest Products Exports

Forest products exports from Ghana were significantly affected by GDP (proxy for national income), export price of wood products, and size of Ghana's external debt (Table 2). The inverse correlation between GDP and forest products exports suggests that increasing national income (GDP) reduces the need for more export revenue, thereby decreasing forest products exports. In contrast, higher external debt obligations increase the need for more export revenue, and hence increases forest products exports. The negative sign on export price suggests that falling international wood product prices leads

Table 2. Regression Results of Forest Products Exports, Fuelwood Consumptions, and Cocoa Production Equations

a) Forest Products Exports

	INTERCEPT	GDP	EXPRICE	EXTDEBT	FORAREA%
	423.48	-15.236	-0.459	0.0594	85.169
	(20.391)[a]	(-2.457)	(-2.507)	(2.369)	(1.638)
Standardized Coefficient		-0.145	-0.398	0.218	0.391
Elasticity (at Mean)		-0.479	-0.549	0.279	0.421

R^2 = 0.742; Durbin-Waston = 2.008

b) Fuelwood consumption

	INTERCEPT	GDP	CTOTALPOP	FORAREA	PRORIGHTS	TIME
	10041.00	-0.1027	0.96E-05	-0.0179	-0.5176	-4.7703
	(2.988)	(-2.505)	(2.364)	(-0.545)	(-5.680)	(-2.844)
Standardized Coefficient		-0.2789	0.3784	-0.0568	-0.7813	-0.5572
Elasticity (at Mean)		-0.0538	0.0864	-0.0131	-0.8361	-28.6832

R^2 = 0.77; Durbin-Waston = 2.096

c) Cocoa Production

	INTERCEPT	GDPGROWTH	CAGRICPOP	FORAREA	PRORIGHTS	EXTDEBT	COCOAINDEX	COCOPRICE
	-166.89	201.89	0.227	-0.624	0.369	0.002	227.97	0.493
	(-0741)	(6.515)	(2.874)	(-5.203)	(1.209)	(4.838)	(5.785)	(5.976)
Standardized Coefficient		2.104	0.257	-0.699	0.239	2.711	3.562	0.563
Elasticity (at Mean)		4.00	0.169	-0.487	0.311	2.087	5.228	0.450

R^2 = 0.86; Durbin-Waston = 2.127

[a] t-values are in parenthesis

Table 3. Regression Results of Food Crop Production and Deforestation Equations

a) Food Crop Production

	INTERCEPT	GDPGROWTH	CTOTALPOP	FORAREA	PRORIGHTS	FOODINDEX
	6.632	-0.00212	0.109E-06	0.001	-0.0085	0.182E-05
	(9.758)[a]	(-1.568)	(2.325)	(2.547)	(-6.569)	(1.487)
Standardized Coefficient		-0.189	0.0325	0.200	-0.798	0.2203
Elasticity (at Mean)		-0.022	0.0160	0.101	-1.897	0.0303

$R^2 = 0.82$; Durbin-Waston = 2.05

b) Deforestation

	INTERCEPT	CFWCON	FORPREXP	COCOPROD	CFOODPROD
	-128.45	2.591	0.036	-0.5665	74.923
	(-0.345)	(4.234)	(2.349)	(-3.154)	(2.814)
Standardized Coefficient		0.612	0.0196	-0.235	0.286
Elasticity (at Mean)		3.634	0.059	-1.409	0.698

$R^2 = 0.79$; Durbin-Waston = 2.00

[a] t-values are in parenthesis.

to increasing exports in order to meet revenue targets. This finding is consistent with the hypothesis by Barbier et al. that lower timber prices discourage efficient harvesting and processing techniques and therefore lead to more logging. Low timber prices can also discourage efforts to prevent local artisans involved in nontraditional forest products activities from exploiting forests (Van Soest).

Forest products export was inelastic with respect to all the explanatory variables studied, as was found for similar variables in Kantz and Redantz. The elasticity of forest product exports was highest with respect to export price (0.55), and consistent with the ranking by the standardized coefficient criterion. In contrast, a 1% increase in external debt increased forest products exports by 0.28%.

Fuelwood Consumption

All the coefficients in the fuelwood consumption equation were different from zero at 5% significance level (except FORAREA), and all had the expected signs (Table 3). The negative sign on GDP (proxy for national income) implies that an increase in national income results in shifts from using wood-based energy to alternative energy sources, thereby reducing fuelwood consumption. When GDP was replaced by GDP per capita (results not reported here but available from authors), the coefficient was still significant at the 1% level, supporting our earlier hypothesis on the substitution effects among alternative energy sources. Although alternative energy sources such as kerosene, liquefied petroleum gas, and electric stoves are more expensive; they are more "user-friendly" and tend to command prestige to the user. Consequently, as income level increases, there is substitution from fuelwood for such alternative energy sources.

As expected, increasing pressure from total population leads to an increase in the amount of fuelwood consumed and, ultimately increases deforestation. When change in total population in the base model was replaced by a change in agricultural population, the variable was insignificant. In contrast, rural population was significantly different from zero at the 5% significance level, when it replaced total population in the base model (results not reported here but are available from the authors), but had a smaller elasticity (0.083) compared to total population (0.086). The results suggest that total population pressure is more important in determining fuelwood consumption than the agricultural population. In addition, rural population which is typically poorer and live closer to forests, tend to depend more on forests for fuelwood energy than urban dwellers, and should not be excluded in national policies for mitigating woodland and forest degradation.

PROPRIGHTS was significant (at the 1% level) and negative, supporting Deacon's (1996) finding that political instability and the accompanying disrespect for property rights and claims to assets following Ghana's numerous military regimes hampers forest cover conservation behavior through fuelwood consumption. Such a political environment tends to encourage encroachment into forest areas; to harvest fuelwood and timber. The final variable in this equation representing technological advancement was significant and negative, suggesting that technological improvements on domestic and small-scale industry energy sources reduce fuelwood consumption. This finding is consistent with innovations in the past decade in terms of various wood energy-saving devices in Ghanaian markets, all targeted at reducing the amount of fuelwood used for cooking and heating.

The elasticity of fuelwood consumption with respect to the various independent variables was highest (in absolute terms) for technological progress (28.68), followed by property rights (0.84) and then total population pressure (0.086). In contrast, elasticity of fuelwood and charcoal consumption was lowest with respect to GDP (0.05). The results imply that priorities at minimizing deforestation through fuelwood consumption should target technological innovations on alternative energy sources, and then strengthening public institutions for enforcing forest protection and respecting clearly defined property rights on forest resources, particularly for the non-agricultural population.

Cocoa Production

As expected, producer price of cocoa had a significant (at the 1% level) and positive effect on cocoa production (Table 2). In addition, macroeconomic forces including GDP growth and Ghana's total external debt had significant positive effects on cocoa production, reflecting the contribution of cocoa to Ghana's GDP, and to export and fiscal revenue. The highly significant effect and positive correlation between cocoa production index and output level supports the hypothesis that cocoa output is influenced more by intensive management activities than by extensive farm management practices (such as increase in acreage). Free common good attitude (FORAERA) was significant and negative, suggesting that perceived large areas of forests do not positively influence the tendency to increase cocoa production. This finding supports the thinking among many analysts that, years of neglect, along with widespread bush fires and a devastating drought in 1983 (which led many farmers to clear cocoa trees and planted other cash and food crops instead), jointly, hamper cocoa production. The result is also consistent with

the fact that some cocoa production occurs in forest areas previously harvested for timber.

Cocoa production was highly elastic with respect to cocoa production index (5.23) and GDP growth (4.00), and was highest (in absolute terms) with respect to cocoa production index compared to the other explanatory variables studied. This finding suggests that increases in cocoa production are due largely to intensive, as opposed to extensive, management effects and represents the single most important factor influencing cocoa production.

Food Crop Production

Population pressure, forest area (i.e. proxy for FCGA) and property rights had significant effects (at 5% level) on food crop production (Table 3). As expected, there was a positive correlation between total population and food production. The positive and significant effect of FCGA suggests that the more the available absolute forest area, the more citizens perceive of the abundance of forests and forest resources, and hence tend to encroach upon forests and/or cultivate new cropland for food. This finding, along with the positive correlation on the property rights variable, suggest the need for more clearly defined rights to forest resource use and strengthening the capacity to enforce forest protection.

The change in food crop production was elastic with respect to property rights, but inelastic with respect to population pressure and the FCGA. In addition, there was consistent ranking of the explanatory variables studied using elasticity and standardized coefficient criteria in decreasing order from property rights, through FCGA to population pressure.

Deforestation

Results of deforestation regressed on the estimated direct causal factors (used as instrument variables of the endogenous variables) are summarized in Table 3. All four direct causes of deforestation were statistically significant at the 5% level. A surprising finding from the analysis was the significant and negative correlation between cocoa production and deforestation. A careful examination of trends in cocoa production in Ghana provides several powerful insights consistent with our finding, and which may affect policy choices and how best to effect public policies on deforestation in the country. First, time series on cocoa production indicate that cocoa production declined steadily throughout the 1970's and early 1980's, reaching a record low level of 166,000 tonnes in 1984. After several years of neglect after independence, and following bush fires and a devastating drought in 1983, many cocoa plantations were abandoned while others were replaced with other cash and food crops. Although a government Cocoa Rehabilitation Program implemented during the late 1980's stabilized the decline, cocoa output has still not yet reached levels recorded in the 1960's. In addition to the steady declines in output, many farmers in Ghana plant cocoa trees under natural forest shade. As alluded to earlier, cocoa plantations which were acquired by clearing forest undergrowth or land that was (partially) logged by timber contractors can lead to minimal effects on forest cover loss. Thus, the steady declines in production and the abandonment of farms, as well as shifts from cocoa to other crops, jointly explain the negative correlation between cocoa production and forest loss. Third, the coefficient on the cocoa production index is not only positive, but highly significant (at 1%), suggesting that

increasing cocoa production is due more to increasing productivity on land cultivated, than to mere increased area cultivated.

The remaining results indicate that increasing fuelwood consumption, forest products exports, and food crop production all increase deforestation in Ghana. Thus, previous government efforts at minimizing deforestation, which targeted only the forestry sector were not only misguided, but also inadequately targeted the key sectors. The effect of fuelwood consumption is an interesting finding with important policy implications on how limited (financial) resources could be prioritized in conserving Ghana's forests. Insights on the impact of fuelwood consumption on deforestation, when examined through the impact of the direct effects on fuelwood energy use, suggest that deforestation can be checked by promoting use of alternative sources of energy for cooking and heating and for small-scale industrial uses.

The elasticity of deforestation was highest with respect to fuelwood consumption (3.6) and lowest with respect to forest products exports (0.059), implying that 1% reduction in fuelwood consumption (forest products exports) will lead to a 3.6% (0.059%) reduction in deforestation. However, the low elasticity with respect to forest products exports does not necessarily mean that deforestation is (absolutely) lowest due to forest products exports; when a smaller fraction of total forest products exports directly result in deforestation, with a larger component coming from regular forest harvest activities, and nontraditional forest products.

The regression coefficient on food crop production was the highest among the four estimated direct variables in the deforestation equation, followed by the coefficient on fuelwood consumption (Table 3). The regression coefficient on fuelwood consumption

indicates that a change in fuelwood consumption by one cubic meter leads to a 2.6 ha loss of forest and/or woodland area. On the other hand, a one tonne increase in food crop production causes 75 ha of deforestation. Kantz and Redantz also found a relatively high coefficient for crop production in deforestation models for African countries and attributed the result to possible wasteful conversion in the process of diverting forestland to food crop production. Such inefficiency in land conversion is consistent with slash and burn shifting cultivation, which is the dominant practice in Ghanaian agriculture. A second but less plausible argument is connected with the hypothesis that the food crop production variable may be capturing deforestation arising from other human activities linked to food production. In addition, non-wood forest products ranging from food, fruits and fibre may be captured through a variable on food production.

Summary

The results from the deforestation equation suggest that forest products exported, fuelwood consumption, and food crop production directly aggravate deforestation. In contrast, several years of neglect of the cocoa industry, along with steady declines in cocoa output, produced primarily under natural forest shade trees, tended to not directly hamper deforestation, but may have indirect effects (working through trade, and monetary and fiscal forces).

The results from this study suggest that policies aimed at minimizing deforestation in Ghana should be classified and then prioritized, based on whether the effects on forest and woodland area loss are direct or indirect (working through key primary causal factors). The results suggest that the causes of deforestation are not linked

to the forestry sector alone, but are also affected by agricultural, economic, demographic, and political factors. Our results indicate that fuelwood consumption and food crop production are two of the leading direct causes of forest and woodland area loss, with the elasticity of deforestation being highest with respect to fuelwood consumption (3.6), and then with respect to food crop production (0.7).

The elasticity of fuelwood consumption was highest with respect to technology (analyzed in terms of a time index) (28.6), and then with respect to state capacity to enforce forest protection and respect property rights (0.84). Thus, government policies for minimizing fuelwood and charcoal consumption through alternative energy source for cooking and heating should be more vigorously pursued and target both rural and urban populations. Macroeconomic variables such as an increasing external public debt and declining income per capita adversely affect deforestation, by working through the first-level causal factors such as forest products exported, and small-scale industry and domestic fuelwood energy needs. Increases in food crop and cocoa productivity through intensive rather than extensive farm management practices also help in forest conservation efforts by minimizing the need to safeguard food security primarily through acreage expansion.

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