Explaining Agricultural Land Expansion and Deforestation in Developing Countries

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In developing economies, especially those without oil and natural gas reserves, the most important source of natural wealth is agricultural land. In these economies, the agricultural land base is expanding rapidly through conversion of forests, wetlands and other natural habitat (Barbier).

López identifies most of Sub-Saharan Africa, parts of East and South East Asia and the tropical forests of South America as regions with "abundant land" and open-access resource conditions that are prone to agricultural expansion. Widespread land and resource conversion is occurring in many of these areas, mainly due to the high degree of integration of rural areas with the national and international economy as well as population pressures. Agricultural land expansion in many tropical regions is also spurred by the poor intensification of agriculture in many tropical developing countries, where use of irrigation and fertilizer is low (FAO 1997 and 2003).

This paper explores further the economic factors underlying agricultural land expansion and tropical deforestation in developing countries. The main focus is on land use change in the *tropics*, as this is where the majority of the world's poorest

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countries are located.[1] The paper first provides a brief summary of global tropical forest and land use trends. This is followed by an overview of cross-country analyses of deforestation and agricultural land expansion, and from this review an empirical analysis is proposed and applied to a new cross-country data set.

Global Tropical Forest and Land Use Trends

During 1980-1990, over 15 million hectares (ha) of tropical forest were cleared annually, and the rate of deforestation averaged 0.8% per year (FAO 1993). Over 1990-2000, global tropical deforestation slowed to less than 12 million ha per year, or an annual rate of 0.6%, although there were substantial regional differences in deforestation (FAO 2001). Stratified random sampling of 10% of the world's tropical forests reveals that direct conversion by large-scale agriculture may be the main source of deforestation, accounting for around 32% of total forest cover change, followed by conversion to small-scale agriculture, which accounts for 26% (FAO 2001). Intensification of agriculture in shifting cultivation areas comprises only 10% of tropical deforestation, and expansion of shifting cultivation into undisturbed forests only 5%.

Thus in most developing economies the decline in forest and woodlands is mainly the result of land conversion, in particular agricultural expansion for crop production (FAO 1997 and 2003). Land expansion occurring in tropical regions appears to be related to structural features of the agricultural sectors of developing economies, such as low agricultural productivity and input use. Poor agricultural intensification and development in turn means pressure to convert forests and other marginal lands to crop production. Various studies suggest that these structural conditions are influences, both directly and indirectly, by economic policies (Barbier; Coxhead and Jayasuriya). Although improvements in cropping intensity and yields are expected to reduce the developing world's dependency on agricultural land expansion over 1990-2010, about 19% of the contribution to total crop production increases in poorer economies are likely to be derived from expansion of cultivated land (FAO 1995). Throughout the developing world, cultivated land area is expected to increase over 47% by 2050, with about 66% of the new land coming from deforestation and wetland conversion (Fischer and Heilig).

Factors Determining Agricultural Land Expansion

As the major cause of forest loss in developing countries is conversion to agriculture, a cross-country analysis of agricultural land expansion should also provide insights into the factors influencing tropical deforestation. Equally, previous studies of tropical deforestation may suggest some of the possible effects of growth, income per capita and other macroeconomic factors on agricultural land expansion in the tropical developing regions of Latin America, Africa and Asia.

Barbier and Burgess survey these studies and find that four distinct analytical frameworks motivate cross-country estimations of the causes of agricultural land conversion and tropical deforestation: i) the environmental 'Kuznets' curve (EKC) hypothesis, ii) competing land use models, iii) forest land conversion models, and iv) institutional models.[2] From these analytical frameworks, the authors identify certain economic factors that may determine tropical agricultural land expansion, and thus key appropriate variables to include in a cross-country regression: i) per capita income and income squared terms to test for a possible EKC relationship; ii) in the absence of adequate cross-country data for agricultural input and output prices, land rent and other price data, certain "structural" variables, such as agricultural yield, cropland share of land area, agricultural export share, and growth in agricultural value added, to capture country-by-country differences in agricultural sectors and land use patterns; and finally, iii) key institutional factors thought to influence land expansion and deforestation (corruption, political stability, rule of law).

Estimation Procedure

Thus a possible "synthesis" model for a cross-country analysis of the effects of economic factors on agricultural land expansion in developing regions might look like:

(1) $\frac{A_{it} - A_{it-1}}{A_{it}} \times 100 = b_0 + b_1 Y_{it} + b_2 Y_{it}^2 + b_3 s_{it} + b_4 z_{it} + b_5 q_{it} + \mu_{it}$, for country *i* at time *t*,

where $(A_{it} - A_{it\text{-}1})/A_{it}$ represents expansion in agricultural land area, Y_{it} is per capita income, s_{it} is a vector of "structural" variables representing country-by-country differences in agricultural sectors and land use patterns, z_{it} represents other exogenous explanatory variables, such as rural population growth and macroeconomic variables, and μ_{it} is the error term. Finally, as institutional factors (q_i) tend to be invariant with time, two versions of the model can be tested, one without and one including q_i.

Barbier and Burgess estimated a version of equation (1) using annual panel data from tropical Latin America, Asia and Africa over 1961-94. Building on their results, the present analysis of tropical agricultural land expansion of equation (1) has been updated for the period 1960-99, as well as modified to reflect the availability of new data and better indicators. For example, the *World Bank Development Indicators* for 1960-1999 have better coverage across countries for data on rural population growth and growth in agricultural value added, which are used in place of population growth and GDP growth from the previous analysis of Barbier and Burgess. In addition, the latter analysis did not have access to the new World Bank data set on governance indicators by Kaufmann, Kraay, and Zoido-Lobaton, which are used here to represent q_i.

The dependent variable in the new analysis is again the percentage annual change in arable and permanent cropland area in each country. The EKC variables (Y_{it}, Y_{it}^2) are represented by gross domestic product (GDP) per capita in constant values (1995 $) and by GDP per capita squared, respectively. The structural variables (s_{it}) are cereal yield, cropland share of total land area, agricultural export share of total merchandise exports and growth in agricultural value added. The additional explanatory variables (z_{it}) are rural population growth and the terms of trade (TOT) for each country. The latter variable is represented by an index of export to import prices (1995 =100). Finally, as the influence of the TOT on a country's export performance may be influenced by the degree of resource-trade dependence of the economy, the terms of trade variable has also been interacted with the share of agricultural and raw material exports as a percentage of total exports of each country. Further support of this interaction effect is provided by Wunder, who finds evidence that an increase in an economy's TOT, principally through expansion of oil exports and price booms, might affect how other sectors, especially expansion of non-oil primary product exports, influence tropical deforestation.

Data

The source of data used for the EKC variables (Y_{it}, Y_{it}^2), the structural variables (s_{it}) and the additional explanatory variables (z_{it}) was the World Bank's *World Development*

Indicators, which has the most extensive data set for key land, agricultural and economic variables for developing countries over the period of analysis.

Three institutional factors (**q_i**) were incorporated into the new analysis of model (1): indicators of control of corruption, political stability/lack of violence and rule of law. The source used for these data is a recent project on governance conducted by the World Bank, which put together a measure of each of the above three institutional factors and other governance indicators for 178 developing and advanced economies (Kaufmann, Kraay, and Zoido-Lobaton). As the control of corruption, political stability/lack of violence and rule of law indicators cover the broadest range of developing countries to date of any comparable indicator, it is ideal for our analysis. Each governance indicator is indexed on a scale of –2.5 (lowest value) to 2.5 (highest value). However, as each indicator is a single point estimate in time (based on survey data for 1997-8), including this time-invariant institutional index essentially amounts to incorporating a "weighted" country-specific dummy variable in the panel regression (Baltagi).

Results

Table 1 reports the regression results. The model was first applied to the sample of all tropical developing countries, without any of the institutional variables included. Subsequent versions of the model were then tested with the inclusion of the three institutional factors comprising **q_i**, i.e. control of corruption, political stability/lack of violence and rule of law. Table 1 reports the regressions that contain each of these institutional indicators in turn, as well as an interaction term between the institutional variable and the terms of trade (TOT).[3] The purpose of the latter interaction term is to test the hypothesis that institutional factors might influence economy-wide export performance, especially in countries dependent on natural resource exploitation such as the conversion of forests (Ascher; Ross). The result is that the degree to which there is corruption, political stability and the rule of law in a country may influence how TOT changes affect agricultural land expansion.

Both one-way and two-way fixed and random effects models were applied. As indicated in table 1, the chi-squared and F-tests for the pooled models as well as the LM statistic test for the null hypothesis of no individual effects. As these tests are significant, they suggest rejection of the ordinary least squares model. The Hausman test indicates that the random effects model is preferred over fixed effects. For all four regressions in table 1, the one-way specification was chosen over the two-way random effects specification based on the likelihood ratio test. In addition, the significance of individual coefficients and the overall explanatory power of the estimation were superior for the one-way model.

The results in table 1 indicate that the model is strongly robust with regard to key structural variables, s_{it}, that capture country-by-country differences in agricultural sectors and land use patterns, most notably agricultural export share, cropland share of land area, and growth in agricultural value added. Only one structural variable, cereal yield, is not significant in any versions of the model. Moreover, the signs of the coefficients of the significant structural variables are as expected; tropical agricultural expansion increases with agricultural export share and growth in agricultural value added, but declines with the share of permanent and arable land to total land area.

However, the regressions in table 1 do not support the EKC hypothesis as an explanation of agricultural land expansion in tropical developing countries. Neither GDP per capita nor GDP per capita squared are significant explanatory variables in any versions of the model, and they also failed the joint significance test. Rural population growth is a significant explanatory variable only in the model version without institutional variables. As expected, increasing rural populations are associated with greater agricultural land expansion.

Of the institutional variables, only control of corruption appears to influence agricultural land expansion. In this version of the model, not only does control of corruption have a direct influence on land expansion but also indirectly through influencing the terms of trade. Also, the TOT now has both a direct influence and an indirect one through an interaction with agricultural export share. In terms of direct effects, a TOT rise appears to spur agricultural land expansion, whereas increased (less) control of corruption slows (speeds) agricultural expansion. However, both greater corruption (i.e. a fall in the control of corruption indicator) and increased agricultural export share tend to dissipate, rather than augment, the TOT influence on agricultural expansion. Similarly, higher terms of trade tend to reduce the impacts of agricultural export share and corruption on land conversion.

Both of these interaction effects have an intuitive explanation. For instance, suppose government regulations and other instruments exist to control agricultural land expansion, but if government officials are corruptible, private economic agents will bribe officials to circumvent land control policies. It follows that improved TOT and a more corruptible government will lead to higher bribes being paid for any given level of land conversion. However, if corrupt officials experience diminishing marginal utility from bribes, then the government may respond by slowing down the rate of conversion as more bribes are paid. Wunder provides another explanation of this interaction effect for some tropical countries. For example, if the TOT appreciation is due to an oil boom, then one consequence is higher rents in the oil and non-trade good sectors. Corruptible officials will therefore be able to enrich themselves by diverting more resources away from non-oil primary product sectors, including agriculture, that are mainly responsible for deforestation. The result is again a slowing down of agricultural land expansion and forest conversion.

Equally, a rise in the terms of trade coupled with a higher agricultural export share will lead to greater foreign exchange earnings for any given level of land conversion. This may lead to two distinct processes to slow land conversion. First, as hypothesized by Wunder, the resulting currency appreciation and simultaneous expansion of the non-trade goods sector will cause contraction in the agricultural and raw material export sector, and any resulting decline in deforestation will be larger given the importance of the latter sector to the economy.[4] In addition, increased foreign exchange may also be subject to diminishing returns, especially if there is a general increase in imported consumption, and as a result agricultural expansion may slow. The economy will be able to increase its imports, especially imported consumption goods, for a given level of agricultural land expansion. If consumers in the economy experience diminishing marginal utility of consumption of imported goods, then the result may be a decline in land conversion.

Table 2 indicates the total elasticity effects of the significant variables influencing tropical land conversion, including any interactions, which are evaluated at the sample regression means for the relevant variables. The most interesting results are for the regression incorporating the control for corruption indicator, which includes the interaction effects of the TOT with agricultural export share and the control of corruption. For example, a 1% rise in the terms of trade would have a direct impact of increasing land conversion by 1.38%. Although this elasticity effect will be moderated by any interaction effect with agricultural export share (-0.31%), it is more than reinforced by interaction with greater control of corruption (0.70%). The result is that the total elasticity effect of a 1% rise in the terms of trade is an increase in land conversion by 1.77%. Equally, the moderating effect of the level of the terms of trade on agricultural export share suggests that a 1% increase in resource dependency may lead to only a 0.16% increase in agricultural land expansion. Finally, the interaction between the terms of trade and greater control of corruption may overwhelm the latter's direct influence on limiting land conversion, so that a 1% reduction in corruption may actually increase land conversion by 0.13%.

Conclusion

Many low and middle-income economies are rapidly changing land use, by converting forests, woodlands and other natural habitat to agriculture and other land-based development activities. In all tropical regions of the world, deforestation is occurring at around 12 million ha per year, mainly the result of agricultural land expansion.

The key "structural" agricultural variables that are significant in the cross-country analysis of tropical agricultural land expansion appear to support this link between agricultural development and land conversion in poor economies. For instance, agricultural export share, growth in agricultural value added and rural population growth are positively associated with agricultural land expansion. In contrast, the share of permanent and arable cropland in total land area is negatively associated with land conversion. Together, these two effects tell us that, if a developing economy has a sizable "reserve" or "frontier" of potential cropland available, increased conversion of this frontier land will occur as agricultural development proceeds in the economy.

Greater dependency on agricultural and raw material exports in developing countries is also associated with land conversion. Developing countries that are more dependent on non-oil primary products for their exports are more likely to expand agricultural land. Corruption appears to be the only institutional factor affecting land expansion. The direct effect is as expected; increased corruption leads to greater deforestation. However, these resource dependency and corruption effects on land conversion may depend on what happens to a country's terms of trade. The presence of these significant interaction effects between the terms of trade and corruption and primary product export dependency suggest caution in assuming that an important policy mechanism by which the rest of the world can reduce land conversion in developing economies is through sanctions, taxation and other trade interventions that reduce the terms of trade of these economies.

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Table 1. Tropical Arable and Permanent Cropland Expansion (% annual change), 1960-99

	Cross-Country Estimations[a]			
	No Institutional Variables	Control of Corruption	Political Stability	Rule of Law
	(N = 1,526)	(N = 1,362)	(N = 1,362)	(N = 1,455)
Explanatory Variables	(Y = 0.967%)[b]	(Y = 0.996%)	(Y = 0.996%)	(Y = 1.039%)
GDP per capita ⁄ 10^3	-0.128	0.051	-0.109	0.056
(constant 1995 $)	(-0.40)	(0.16)	(-0.33)	(0.17)
GDP per capita squared ⁄ 10^7	0.180	-0.176	0.034	-0.013
	(0.25)	(-0.26)	(0.05)	(-0.19)
Terms of trade ⁄ 10^2	0.186	1.210	0.256	0.522
(1995 = 100)	(0.75)	(2.96)**	(0.89)	(1.42)
Agricultural export share ⁄ 10^2	3.407	4.370	3.678	2.985
(% of merchandise exports)	(2.02)*	(2.67)**	(2.18)**	(1.75)†
Terms of trade × Agricultural export share	-2.071	-2.539	-2.099	-1.628
⁄ 10^4	(-1.59)	(-2.01)*	(-1.59)	(-1.21)
Growth in agricultural value added ⁄ 10^2	1.621	1.585	1.562	1.818
(% annual change)	(1.93)*	(1.81)†	(1.78)†	(2.09)*
Cereal yield ⁄ 10^4	0.711	-0.886	-1.409	-1.488
(kg per hectare)	(0.47)	(-0.59)	(-0.92)	(-0.94)
Rural population growth	0.213	0.091	0.077	0.165
(% annual change)	(2.14)*	(0.86)	(0.71)	(1.56)

Agricultural land share ⁄ 10^2	-1.632	-1.333	-1.722	-1.282
(% of total land area)	(-2.12)*	(-1.73)†	(-2.23)*	(-1.65)†
Control of corruption		-1.404		
(no control = -2.5; no corruption = 2.5)		(-2.26)*		
Control of corruption × Terms of trade ⁄ 10^2		1.510		
		(2.79)**		
Political stability			0.327	
(no stability = -2.5; no instability = 2.5)			(0.76)	
Political stability × Terms of trade ⁄ 10^2			0.036	
			(0.11)	
Rule of law				-0.406
(no law = -2.5; full law = 2.5)				(-0.76)
Rule of law × Terms of trade ⁄ 10^2				0.621
				(1.44)
Kuznets curve	No	No	No	No
χ-test for pooled model	154.064**	114.79**	118.318**	130.181**
F-test for pooled model	2.297**	1.994**	2.059**	2.085**
Breusch-Pagan (LM) test	38.58**	15.70**	22.97**	23.10**
Hausman test	13.10	14.57	16.05	11.74
Preferred model	One-way random effects	One-way random effects	One-way random effects	One-way random effects

Notes: [a] t-ratios are indicated in parentheses.

[b] *N* is the number of observations. *Y* is the mean of dependent variable for the regression sample.

** Significant at 1% level, * significant at 5% level, † significant at 10% level.

Table 2. Total Elasticity Effects for Tropical Agricultural Land Expansion

Effects[a]	No Institutional Variables	Control of Corruption	Political Stability	Rule of Law
Terms of trade				
Terms of trade only		1.375		
Agricultural export share effect		-0.305		
Institutional variable effect		0.700		
Total terms of trade effects		1.770		
Agricultural export share				
Agricultural export share only	0.364	0.463	0.390	0.297
Terms of trade effect		-0.305		
Total export share effects	0.364	0.159	0.390	0.297
Institutional variables				
Institutional variable only		-0.575		
Terms of trade effect		0.700		
Total institutional effects		0.125		
Growth in agricultural value added	0.047	0.045	0.044	0.051
Rural population growth	0.329			
Agricultural land share	-0.303	-0.237	-0.315	-0.219

Notes: [a]Only effects significant at 10% level or better are indicated. All effects are indicated as elasticities evaluated at the means of the respective regression samples

Notes

[1] The designation of countries in Latin America, Asia and Africa as "tropical" follows the classification according to the FAO's 1990 and 2000 Forest Resource Assessments (see FAO 1993 and 2001).

[2] The environmental Kuznets curve (EKC) hypothesis states that an environmental "bad" first increases, but eventually falls, as the per capita income of a country rises. Although the EKC model has generally been applied to pollution problems, some studies have examined whether it also holds for global deforestation. See Dasgupta et al. for a recent survey of the EKC literature.

[3] Including two or all three of the institutional indicators in the regressions often lead to collinear regressors, or to regressions that were not very robust. In addition, for our sample of tropical developing countries, these indicators prove to be highly correlated. For example, the simple pair-wise correlations between control of corruption and political stability/lack of violence and rule of law were 0.54 and 0.66 respectively.

[4] According to Wunder, this phenomenon is particularly relevant for oil producing tropical countries through a "Dutch disease" effect that causes the oil and non-traded sectors of the economy expand at the expense of non-oil trade sectors. In most tropical developing countries, the latter are typically agriculture, fisheries, forestry and non-oil mining, which are also the sectors most associated with forest conversion. As a consequence, a country with a large non-oil primary product export sector is likely to experience a greater slow down in forest land conversion as a result of the rising terms of trade from an oil price boom.