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Chapter

THE TRENDS AND THE DRIVERS OF DEFORESTATION: A CROSS-COUNTRY SEEMINGLY UNRELATED REGRESSION ANALYSIS FOR THE REDD+ POLICIES

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ABSTRACT

Policies for Reducing Emissions from Deforestation and Forest Degradation, known as REDD, and enhancing forest carbon stocks, known as REDD+, could provide a way for tackling global warming and climate change. In this regard several proposals were designed, yet their implementation poses significant methodological problems. One of those problems can be the *interactions* between the *direct* and *indirect* causes (drivers) of deforestation. Deforestation is a transformation of forestland for various land uses. This chapter therefore analyses trends in world deforestation in relation to different geographical regions and its drivers. A cross-sectional econometric model, *recursive in nature*, is estimated in two stages for addressing the interaction between the causes. Firstly, the *direct* causes of deforestation are regressed on *indirect* causes, by

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Seemingly Unrelated Regression (SUR) estimation to account for the correlations between the direct causes. Secondly, the SUR estimates of the direct causes are used for the regression of deforestation equation. The statistical evidences show prevalence of omitted variables for the indirect causes, as well as correlations between the direct causes. The SUR estimates are therefore efficient than OLS estimates. The results are discussed, in relation to Asian, African and Latin American regions, to provide guidance for designing effective REDD+ policies.

Keywords: Drivers of deforestation, climate change, REDD+, two-stage estimation, SUR

1. INTRODUCTION

Tropical forestation is one of the most serious environmental problems in recent times. It has become an issue of global concern because of tropical forests' relevance in limiting the greenhouse effects and biodiversity conservation. Between 1990 and 2005, forest area decreased by an average of 13 million hectares per year (excluding reforested area) [16], with major consequences for climate and biodiversity. Deforestation is now the second leading cause of greenhouse gas emissions, just behind industrial emissions. At global level, tropical deforestation accounts for about 25 percent of the heat trapping emissions [20]. Tropical rain forests, in particular, constitute about 41 percent of total tropical forest cover on the earth's land surface, and it is the richest and the most valuable ecosystem that provides habitation for 50-90 percent of all species on earth [31]. Deforestation also affects economic activity and threatens livelihood and cultural integrity of forest-dependent people at local level.

Deforestation happens in countries where the status of development and welfare of the citizens are crucial factors in determining the extent of the forest loss. Poverty, over-population and indebtedness accentuate deforestation in low-income countries. The requirement for income and economic growth result in growing demand for agricultural and forest derived products. The main causes of deforestation are due to *expansion of arable land and fuel wood need for local populations* [7], [9] and for the desire for countries to increase their foreign exchange earnings from trade in *tropical timber and export crops.* For governments of many developing countries these are the easiest and the most accessible ways of responding to their ever increasing economic pressures.

However, the studies of deforestation do not provide a clear picture of its causes and the causes seem to vary from place to place. For example, international timber trade played a major role in Southeast Asia but only a minor role in Latin America whereas cattle ranches (pasture) caused much deforestation in Latin America than anywhere else [9]. Although tropical forests are mostly located in low income countries, deforestation is also now a global problem due to climate change, and developed countries are now aware that a *laissez-faire* policy for managing the tropical forests will jeopardize the future of the planet and their own development paths. In this regard international community is actively looking for global solutions and is trying to identify policy instruments that could persuade tropical countries to curb their deforestation.

But, as a consequence of increasing economic pressures, the developing countries are also not in a position to reduce their deforestation activities without compensation from the developed countries. Developing countries argue that a global solution to the deforestation issue must include a North-South financial transfer scheme to compensate for the revenue foregone, and also for the costs associated with monitoring and controlling the exploitation of their forests, such as managing corruption and illegal logging by local and foreign corporations. Various international mechanisms have been tested in the past and new proposals are being developed such as the REDD policy (Reducing Emissions from Deforestation and forest Degradation) under the UN-REDD program. Lately the REDD policy has also included the objectives for enhancing forest carbon stocks, known as REDD+ [2].

Under the REDD policy, a North-South financial transfer to compensate countries for avoided deforestation, may have both direct and indirect impacts on deforestation. The direct impact is due to the conditionalities of the REDD instruments and the way they are designed, and the indirect impact is due to their feedback effects through the drivers (causes) of deforestation such as rural and urban income, poverty rates, agricultural productivity, and foreign exchange earnings. The net effects of these policy instruments on deforestation are however not straightforward to the recipient countries. They can either be positive or negative and this has implications for the forest cover changes and the forest transitions in the forested countries [8].

This chapter therefore empirically analyses a *two-stage econometric model* for the interaction between the direct (as *endogenous*) and the indirect (as *exogenous*) causes of deforestation. *Seemingly Unrelated Regression* (SUR) analysis applied for a set of cross-country data covering the geographical regions of Latin America, Africa and Asia. The model estimates can provide some conventional facts for the causes of deforestation, concerning the geographical regions and the period of analysis, and also directions for designing the REDD+ policies as effective as possible.

This chapter is organized as follows. Section 2 provides an overview of the trends in world deforestation. Section 3 describes the econometric model of deforestation for the interaction between the direct and indirect causes. Section 4 details the data and method. Results and discussion are given in Section 5, following the conclusion in Section 6.

2. An Overview of the Trends in World Deforestation

Deforestation happens in countries where the status of development and welfare of the citizens are crucial factors in determining the extent of the forest loss. Poverty, over-population and indebtedness accentuate deforestation in low-income countries. The requirement for income and economic growth result in growing demand for agricultural and forest derived products. Such trends are unlikely in many developed countries where higher levels of (national) income growth lead to changes in demand for goods and services, with greater demand for environmental services. This trend is a positive forest cover change over time and termed as *forest transition* [24]. The forest transition hypothesis argues that it is unlikely that massive deforestation will be maintained over time, as the opportunity costs of deforestation increase with increased forest scarcity [13], [14], [23]. It is also argued that forest scarcity reduces incentives to deforest and can lead to reforestation [26].

Deforestation has occurred in the temperate and sub-tropical areas in 19th and 20th centuries and it is no longer significant in the developed temperate countries. Many temperate countries are now recovering their forest area. Tropical deforestation is relatively a modern event that gained momentum in the second half of 20th century. The FAO Global Forest Resources Assessment 2010 indicates considerable deforestation in the world during 1990-2010 but this was almost entirely confined to tropical regions. A summary of the trends in word deforestation for the last two decades 1990-2010 is shown in Table 1. The figures show that there was considerable deforestation in the world during 1990-2010, but this was almost confined to tropical regions (see table 1).

Table 1. Annual change in forest area by region and subregion, 1990-2010 (Source [15])

Region/subregion	1990-2000		2000-2010	
	1000 ha/year	%	1000 ha/year	%
Eastern and Southern Africa	-1841	-0.62	-1839	-0.66
Northern Africa	-590	-0.72	-41	-0.05
Western and Central Africa	-1637	-0.46	-1535	-0.46
Total Africa	-4067	-0.56	-3414	-0.49
East Asia	1762	0.81	2781	1.16
South and Southeast Asia	-2428	-0.77	-677	-0.23
Western and Central Asia	72	0.17	131	0.31
Total Asia	-595	-0.10	2235	0.39
Russian Federation (RF)	32	n.s	-18	n.s
Europe (excluding RF)	845	0.46	694	0.36
Total Europe	877	0.09	676	0.07
Caribbean	53	0.87	50	0.75
Central America	-374	-1.56	-248	-1.19
North America	32	n.s	188	0.03
Total North and Central America	-289	-0.04	-10	-0.00
Total Oceania	-41	-0.02	-700	-0.36
Total South America	-4213	-0.45	-3997	-0.45
World	-8327	-0.20	-5211	-0.13

The figures also show that deforestation was at the rate of 8.3 million hectares per year (or, 0.2 %) during 1990-2000, but it decreased to 5.2 million hectares per year (or, 0.13%) during 2000-2010. This change in deforestation rates implies that the annual net loss during 2000-2010 is 37 percent lower than the annual net loss during 1990-2000. As a region/sub-region, South America lost about 4 million hectares per year during the last decade, followed by Africa with 3.4 million hectares and the Oceania with 7 hundred thousand hectares. Oceania suffered mainly due to severe drought and forest fires in Australia that had exacerbated the loss. However, the forest area in North and Central America remained stable during the last decade. The forest area in Europe continued to expand during the last decade, although at a slower rate of 7 hundred thousand hectare per year compared to the 1990s with 9 hundred hectares per year. Asia lost around 6 hundred thousand hectare per year during the 1990s but gained more than 2.2 million hectares per year during the last decade. Table 2 shows the ten countries with the largest net loss per year for the last two decades 1990-2010. The combined net loss of forest area is 7.9 million hectares per year during 1990-2000, but this was reduced to 6 million hectares per year during 2000-2010. This trend is a result of the reductions in Indonesia, Sudan, Brazil and despite increased net losses in Australia [15]. Brazil and Indonesia had the highest net loss of forest during the decade of 1990, but significantly reduced the rate of loss during the last decade. They together accounted for almost 40 percent of the net forest loss during the 1990s. Even though Brazil was the top deforesting country by area the forests in Brazil are so extensive therefore this represents a loss of about 0.5 per cent per year. Further, it is reported that about twenty-eight countries and areas had an estimated net loss of one percent or more of their forest area per year [15]. And the five countries with the largest annual net loss are reportedly Comoros (-9.3%), Togo (-5.1%), Nigeria (-3.7%), Mauritania (-2.7%) and Uganda (-2.6%). The Global Forest Resources Assessment [15] also provides estimates for the ten countries with the largest net gain in forest area during 1990-2010. The ten countries had a combined net gain of forest area of 3.4 million hectares per year.

Table 2. Countries with largest annual net loss of forest area, 1990-2010 (Source [15])

Country	Annual change 1990-2000		Country	Annual change 2000-2010	
	1000 a/year	%		1000 ha/year	%
Brazil	-2890	-0.51	Brazil	-2642	-0.49
Indonesia	-1914	-1.75	Australia	-562	-0.37
Sudan	-589	-0.80	Indonesia	-498	-0.51
Myanmar	-435	-1.17	Nigeria	-410	-3.67
Nigeria	-410	-2.68	Tanzania	-403	-1.13
Tanzania	-403	-1.02	Zimbabwe	-327	-1.88
Mexico	-354	-0.52	DR of the Congo	-311	-0.20
Zimbabwe	-327	-1.58	Myanmar	-310	-0.93
DR of the Congo	-311	-0.20	Bolivia	-290	-0.49
Argentina	-293	-0.88	Venezuela	-288	-0.60
Total	-7926	-0.71	Total	-6040	-0.53

Further, nineteen countries had a net gain of one percent or more in forest area. The gains in forest area are due to afforestation efforts and natural expansion of forests.

The area of other wooded land globally decreased by about 3.1 million hectares per year during 1990-2000 and by about 1.9 million hectares per year during the last decade (2000-2010). The area of other wooded land also decreased in both decades for the African, Asian and South American regions [15].

3. THE ECONOMETRIC MODEL OF DEFORESTATION

The causes of deforestation can be studied at different levels [3], [9]. However, an empirical analysis of interaction between the causes at different levels can explain the complexity of deforestation process. To keep the model setting within manageable limits, this study empirically analyses the interaction between the causes at two different levels as *direct* and *indirect* causes. This study therefore follows the model setting detailed in [22] and applied by others in different contexts (for example, [34]).

The model is both *two stages* and *recursive* system of five equations. The first equation estimates the deforestation as dependent variable and four direct causes as independent variables. At the first stage, the equations for the four direct causes are estimated in terms of the indirect causes. And at the second stage, the deforestation equation is estimated based on the estimated values of the direct causes at the first stage.

The model is applied for a set of cross-sectional data for the countries of African, Asian and Latin American regions. The model assumes that the direct causes are independent to each other and the error terms of their equations are not correlated.

However, it is considered in this study that the equations for the direct causes are *contemporaneously correlated* through the respective error terms, i.e. *seemingly unrelated regressions* (SUR)[1]. It is reasonable to allow for such correlation between these equations in terms of their error terms as they can represent the omitted variables in the model.

[1] The SUR estimation itself will correct for the heteroscedasticity in the model.

3.1 Deforestation Equation

For the deforestation equation the direct causes can be grouped into two categories: the demand of forest products and the demand of forest land for alternative land use.

The deforestation equation (DEF) is therefore given as a vector of four direct causes, namely, roundwood (forest products) consumption (RWC), forest products exports (FPE), annual change in cropland (CCL) and annual change in pasture (CPL).

These direct causes are considered as the main drivers of deforestation in a global context[2]. Each direct cause is given by a vector of indirect causes as explained below:

$$Y_1 = \alpha_1 + \beta_1 X_1 + \varepsilon_1 \quad (1)$$

$$X_2 = \alpha_2 + \beta_2 Z_2 + \varepsilon_2 \quad (2)$$

$$X_3 = \alpha_3 + \beta_3 Z_3 + \varepsilon_3 \quad (3)$$

$$X_4 = \alpha_4 + \beta_4 Z_4 + \varepsilon_4 \quad (4)$$

$$X_5 = \alpha_5 + \beta_5 Z_5 + \varepsilon_5 \quad (5)$$

where Y_1 is the amount of deforestation, X_1 is the vector for the four direct causes and ε_1 is the error term. Intercept is represented by α_1 and β_1 is a row vector of the slope coefficients corresponding to the four explanatory variables.

Equations for the direct causes are expressed by X2, X3, X4 and X5, respectively, in terms of vectors of indirect causes by Z2, Z3, Z4 and Z5, respectively. At first stage, the OLS estimation assumes that $covar\ (\varepsilon_1\ \varepsilon_i) = 0$ *for* $i = 2, 3, 4,$ *and* 5. This assumption implies that equation 1 is not linked to equations 2, 3, 4, and 5 by the correlation of omitted variables. At second stage, the SUR estimation assumes that $covar\ (\varepsilon_{it}\ \varepsilon_{jt}) = E\ [\varepsilon_{it}\ \varepsilon_{jt}] = \sigma_{ij}$ *for* $i, j = 2, 3, 4$ *and* 5, *and* $i \neq j$. This implies that the error terms of equations 2, 3, 4, and 5 are correlated, *Seemingly Unrelated Regression (SUR)*. The SUR estimation will improve efficiency by accounting for the cross-equation correlations compared to an OLS estimation that ignores such correlations[25].

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[2]Possibly there are other minor causes but they assumed to be represented by the error term.

3.2 Roundwood (Forest Products) Consumption Equation (RWC)

This equation is based on consumer theory that an individual's demand is depends on income and price of the product. However, at a national level, the aggregate consumption will depend upon the national income (GDP). Thus GDP has been used to represent the national income level. The effects of income and prices of forest products on deforestation can be hypothesised differently. Due to limitations in obtaining data for the prices of forest products, total forest area (AFA) has been used as a proxy for the price variable [22], [34] based on the *scarcity of forest products arguments* [27], [8]. The other explanatory variable in the equation is population (POP). Population is a commonly cited variable for deforestation [6], [21], [28]. The coefficients of all three variables are expected to be positive.

3.3 Forest Products Export Equation (FPE)

Economies of developing countries are in general based on the exports from agricultural and forest products. The forest product export will depend on the *comparative advantage* of that product over other products. Since major proportion of exports come from the primary products that are land based, proportion of forest area to the total land area (PFA) is used as an explanatory variable in this equation [22], [11]. The second variable included in the equation is foreign debt (DEBT) as discussed in literature [19], [6], [21], [12], [5], [10].

Export price is the other variable included in the equation [11], [27], [29]. Since export takes place from one country to many countries and also with different types of forest products, it is difficult to specify one export price of forest products for each country. For this reason, terms of trade (TOT) has been used as a proxy for the export price. However, the effect of TOT on the export of forest products is assumed as negative, because the export quantities are the actual exports that represent the demand faced by the exporting countries [22].

The last variable in this equation is economic growth (GDPG). The coefficients of the variables are expected to be positive for PFA, DEBT and GDPG and negative for TOT.

3.4 Change in Cropland Equation (CCL)

Agricultural sector is a major contributor to economies of many tropical countries. It contributes to GDP, employment and exports. Therefore agricultural production index (API) is an explanatory variable for this equation [11], [8]. Further, population growth causes decline in available arable land and scarcity of cropland has caused an expansion into forest areas. This expansion can be due to the migration of people into forest areas for subsistent needs (subsistence farmers) and also to produce export crops (commercial farmers) [4].

Expansion of cropland into forestland is caused by two associated factors, population (POP) and economic growth (GDPG). Population growth causes the subsistence farmers to move into forests while production of export crops by commercial farmers boosts the economic growth [4]. The association of GDPG with exports of agricultural products is same as for the forest products export. The other variable that will determine the cropland expansion into the forestland is availability of the forestland (AFA). The coefficients of all four variables are expected to be positive [22].

3.5 Change in Pasture Equation (CPL)

Changes in cropland and pasture are due to conversion of forestland for alternative land uses. However the conversion of forestland to pasture has been explained by a different mechanism than that for the cropland. Also the conversion of forestland to pasture is concentrated mainly in Latin American countries where large-scale cattle ranching operations are driven for the purpose of meat exports [11], [19], [29]. Because of the emphasis given for the meat export, conversion of forestland to the pasture is considered as parallel to the process involved with the forest products exports, and this equation is estimated only for the Latin American countries. Therefore the explanatory variables for this equation and their effects are considered as same as for the FPE equation.

The *two stages estimation* is conducted as follows. At the first stage, RWC, FPE, CCL and CPL equations are estimated as a SUR model because their error terms are contemporaneously correlated. The error terms of the equations can also represent omitted variables that are common to all four equations, or specific to a particular equation, for example, general health of the economy, the quality of environmental policies, property-right institutions, land tenures, etc. The error terms can also represent the omitted variables that are common to the forest product equations (RWC and FPE), or the land use equations (CCL and CPL). There are also potential links that can exist between the four equations, by the fact that the effect of migration of farmers (and loggers) from one activity to another in a particular year. Therefore estimating these equations separately will *waste this information* [25].

On the other hand, a useful way to understand the complexities of this system is estimation by the SUR, in which there are *cross-equation correlations*, but otherwise *no simultaneity*. Compared to OLS estimation, which assumes no cross-equation correlations, the SUR method involves GLS estimation and achieves an improvement in efficiency by taking into account (explicitly) the fact that the cross-equation error correlations cannot be zero. At second stage, the DEF equation is estimated based on the estimated values for the RWC, FPE, CCL and CPL equations at the first stage, and with the assumption that the DEF equation is not linked to the other equations by a correlation between the *omitted variables*.

4. Data and Method of Estimation

Deforestation data is a common problem for the empirical studies. *Annual average deforestation* based on the change in forest cover is used as more reliable estimates for the deforestation. The change in forest cover is defined as the net change in natural forests to include expansion of plantations and losses and gains in the area of natural forests. The data for change in cropland between 1991 and 1994 is a difference between the cropland in 1991-1993 and 1992-1994.

The same applies to the data for change in pasture. Because of the time period considered, the sample consists of 52 countries from the three regions (Appendix 1). The units, sources and the explanations for all the variables are given in Table 3.

When estimating the equations by a set of global level data, the regional effects (intercepts) of the regression analysis can be captured by employing dummy variables as DUMLA, DUMAF and DUMAS, respectively, for Latin American, African and Asian regions.

The variation in slopes (coefficients) of different explanatory variables across the regions can be captured by using the regional dummy variables and the global variables.

Table 3. Details of data used for the estimation of deforestation model

Sector	*Variable*	*Explanation*	*Unit*	*Source*
Forest	DEF	Annual average deforestation (1991-2000)	1000 hectares	[17]
	AFA	Absolute forest area (1991-95)	1000 hectares	[33]
	PFA	Percentage of forest area (1991-95)	Percent	[33]
	RWC	Annual round wood consumption 1994	1000 cubic meters	[18]
	FPE	Forest products exports 1994	1000 US$	[18]
Agriculture	CCL	Change in cropland (1991-94)	1000 hectares	[33]
	CPA	Change in pasture (1991-94)	1000 hectares	[33]
	API	Index of agricultural production 1994	Base years 1989-91	www.fao.org
Macro-economic	GDP	Total GDP 1994	Million US$	[32]
	GDPG	Growth rate in GDP 1994	Percent	[32]
	DEBT	Total external debt 1994	Million US$	[32]
	TOT	Terms of trade 1994	Base year 1990	[30]
Demographic	POP	Total population 1994	1000 people	www.fao.org

For example, from the global variable of population (POP) three different regional variables of population are generated by multiplying POP with the respective dummy variables as POP × DUMLA, POP × DUMAF, and POP × DUMAS to represent population in the regions. By this way, if population in the three regions has different effects on roundwood consumption, the coefficients of the three variables will be different, and instead of using only one global variable for population (POP), the use of three variables will improve explanatory power of the regression [22].

On the other hand, if population is found to effect roundwood consumption only for one region, exclusion of population for other two regions will improve explanatory power of the regression. Similarly, if effects of population for all regions are not significantly different, the explanatory power of the regression can be improved by using only the global variable for population (POP). Further, if population has similar effect in two regions but a different effect for third region, the global population variable and the population variable of third region will pick up all the effect, and in this case the coefficient of global population will give the global effect on all three regions and the coefficient of third region's population will give the difference for the third region from the global effect [22].

The above approach is used to capture the variation in coefficients of explanatory variables across the regions when estimating the five equations of the *recursive model*. At the beginning, when estimating each equation, the three regional variables are used for each explanatory variable. Then an appropriate combination of the variables was selected based on the outcome that has high explanatory power of the regression and theoretically consistent results. The equation for pasture was estimated only for the Latin America at the first stage for the reason explained earlier.

5. RESULTS AND DISCUSSION

The SUR estimates of equations at the first stage are given in Table 4. The inference of parameters and the LM test statistics favoured addressing the contemporaneous correlation compared to OLD method which ignores such correlation. At the second stage, the deforestation equation was estimated based on the SUR estimates of the directed causes. The deforestation equation also corrected for heteroscedasticity by White method (Table 5). The estimates of the direct causes are theoretically consistent, except for the effect of population (POP) in cropland equation, and the effects of proportion of forest area (PFA) and GDP growth (GDPG) in pasture equation (Table 4).[3]

[3]The cropland equation also tested with other variables for population (POP) such as population density, agricultural population and agricultural population density, instead of total population. But for all these cases, results were theoretically inconsistent and for that reason the effect of population is not reported. For the pasture equation the effects of proportion of forest area (PFA) and GDP growth (GDPG) were statistically insignificant therefore they are also not reported in the results.

Table 4: Econometric estimates of the indirect causes (standard errors are in parenthesis)

Equation/Variable [@]	SUR estimates
RWC	
Constant	-531.494 (1449.966)
AFA (I)	0.422 (0.308×10^{-1}) ***
AFA (III)	1.157 (0.871×10^{-1}) ***
POP (II)	1.086 (0.703×10^{-1}) ***
POP (III)	0.231 (0.125×10^{-1}) ***
GDP	0.490×10^{-1} (0.222×10^{-1}) ***
R squared	0.978
FPE	
Constant	-17783.466 (87421.427)
PFA (III)	52921.368 (9757.733) ***
TOT (III)	- 17645.229 (3701.721) ***
GDPG (III)	164791.437 (79082.628) **
DEBT	10.163 (2.242) ***
R squared	0.677
CCL	
Constant	-1530. 124 (373.136) ***
DUMLA	1406.222 (382.865) ***
AFA (I)	0.138×10^{-1} (0.827×10^{-3}) ***
API (II)	15.021 (3.599) ***
GDPG (III)	250.074 (58.639) ***
R squared	0.855
CPL	
DUMLA	1602.226 (598.099) ***
TOT (I)	-16.260 (5.770) ***
DEBT (I)	0.142×10^{-1} (0.312×10^{-2}) ***
R squared	0.360

[@] The roman numbers (I), (II) and (III) in parenthesis after the explanatory variables indicate references to Latin American, African and Asian regions, respectively.

Breusch-Pagan LM test statistics: λ = 25.786 *** (chi-sq for six df at 1 % level is 16.81).

The correlation coefficients between the four equations are as follows (where the subscripts 1, 2, 3 and 4 correspond to RWC, FPE, CCL and CPL, respectively): $r_{12} = 0.41$, $r_{13} = 0.21$, $r_{14} = -0.17$, $r_{23} = 0.37$, $r_{24} = -0.29$, and $r_{34} = -0.2$.

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

From the results of deforestation equation (Table 5), the constant term suggests that all three regions have some amount of deforestation (about 61342 hectare per annum) irrespective of the effect captured by the direct causes.

Table 5. Econometric estimates of deforestation equation (standard errors are in parenthesis)

Variable [@]	OLS (White heteroscedasticity correction applied) [©]
Constant	61.342 (27.516) **
RWC (II)	0.276×10^{-2} (0.728×10^{-3})***
FPE (I)	0.238×10^{-3} (0.736×10^{-4})***
FPE (III)	0.186×10^{-3} (0.803×10^{-4}) **
CCL (I)	0.250 (0.105×10^{-1})***
CPL (I)	0.110×10^{-2} (0.230×10^{-1})
R squared	0.776

[@] The roman numbers (I), (II) and (III) in parenthesis after the explanatory variables indicate references to Latin American, African and Asian regions, respectively.
[©] Breusch-Pagan chi-squared = 29.433 *** (chi-sq for five df at 1 % level is 15.09).
*** Significant at 1 % level; ** significant at 5 % level; * significant at 10 % level.

The effect of RWC on deforestation is significant for Africa, the effect of FPE is significant for Asia and the effects of FPE and CCL are significant for Latin America. The results from Tables 4 and 5 can provide an understanding of the *mechanism of deforestation process* across the regions at two levels, considering the period of the data analyzed.

A combination of the results is given in Table 6 for the expected effects. Further the correlation coefficients for equations of direct causes, i.e. correlation between the error terms that represent the omitted variables in the equations, suggest that there are *positive* correlations between the equations for RWC, FPE, CCL (i.e. r_{12}, r_{13} and r_{23}) also negative correlations between the equation for CPL and the others (i.e. r_{14}, r_{24} and r_{34}) as shown in Table 4.

The correlation between the equations for RWC and FPE (i.e. 0.41) implies that these two direct causes, commonly known as *logging* have some positively related variables that are omitted in their equations. Similarly, the correlation of equations for CCL and FPE (i.e. 0.37) implies that they have some positively related variables that are omitted in their equations. This is because there are substantial evidences that *logging increases the expansion of agricultural activity* in tropical forest area by providing access to previously inaccessible areas. It is evident that nearly 70 percent of the primary forest areas brought under the agricultural cultivation are first degraded by commercial logging in these areas [1], [9].

However the negative correlation coefficients for the equation for CPL with the other equations suggest that the pasture equation may have omitted variables that are negatively related to the omitted variables of the other equations. It is also notable that the error terms of the equations not only represent the omitted variables but also other factors such as measurement errors.

6. CONCLUSION

Deforestation is a transformation of forestland for various land uses. This chapter therefore analyses trends in world deforestation in relation to different geographical regions and its drivers.

Table 6. The combined results of the all five equations (for the significant variables)

	Latin America	Africa	Asia
Constant	+	+	+
RWC		+	
AFA	+		+
POP		+	+
GDP	+	+	+
FPE	+		+
PFA			+
GDPG			+
TOT			-
DEBT	+	+	+
CCL	+		
Constant	-	-	-
Dummy	+		
AFA	+		
GDPG			+
API		+	
CPL			
Dummy	+		
TOT	-		
DEBT	+		

A cross-sectional econometric model, *recursive in nature*, is estimated in two stages for addressing the interaction between the causes. Firstly, the *direct* causes of deforestation are regressed on *indirect* causes, by *Seemingly Unrelated Regression* (SUR) estimation to account for the correlations between the direct causes. Secondly, the SUR estimates of the direct causes are used for the regression of deforestation equation. The statistical evidences show prevalence of omitted variables for the indirect causes, as well as correlations between the direct causes. The SUR estimates are therefore efficient than OLS estimates. The results can provide an understanding of the *mechanism of deforestation process* across the different geographical regions at two levels, considering the period of the data analyzed. The results are presented in relation to the Asian, African and Latin American regions and they can provide guidance for designing the REDD+ policies as effectively.

Appendix 1. List of countries for the deforestation model

Africa	Algeria, Angola, Cameroon, Central African Republic, Congo, Congo Democratic Republic, Cote d'Ivore, Equatorial Guinea, Ghana, Guinea, Guinea-Bissau, Kenya, Madagascar, Malawi, Mozambique, Nigeria, Senegal, Sierra Leone, Tanzania, Tunisia, Zambia and Zimbabwe
Latin America	Argentina, Costa Rica, El Salvador, Guatemala, Haiti, Honduras, Jamica, Mexico, Nicaragua, Panama, Trindad and Tobago, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Uruguay and Venizula
Asia	Bangladesh, India, Indonesia, Malaysia, Pakistan, Philippines, Sri Lanka, Thailand and Fiji

REFERENCES

[1]. Amelung, T., Diehl, M. (1992): Deforestation of Tropical Rainforests: Economic Causes and Impact on Development, *Kieler studien*, 241. Tubingen, Mohr, Germany.

[2]. Angelsen, A., Rudel, T. (2013): Designing and Implementing Effective REDD+ Policies: A Forest Transition Approach, Review of Environmental Economics and Policy, 7, 91-113.

[3]. Angelsen, A., Kaimowitz, D. (1999): Rethinking the causes of deforestation: lessons from economic models. *The World Bank Research Observer*, 14 (1), 73-98.

[4]. Angelsen, A., Shitindi, E. F. K., Aarrestad, J. (1999): Why do farmers expand their landinto forests? Theories and evidence from Tanzania, *Environment and Development Economics*, 4, 313-31.

[5]. Arcand, J, L., Guillaumont, P., Jeanneney, S. G. (2008): Deforestation and the real exchange rate. *Journal of Development Economics*, 86, 242-262.

[6]. Capistrano, A. D., Kiker, C. F. (1995): Macro-scale economic influences on tropical forest depletion. *Ecological Economics*, 14, 21-29.

[7]. Chomitz, K. M., Buys, P., De Luca G., Thomas, T. S., Wertz-Kanounnikoff, S. (2007): At loggerheads? Agricultural Expansion, Poverty Reduction, and Environment in Tropical Forests. World Bank Policy Research Report, World Bank, Washington DC.

[8]. Culas R. J. (2012): REDD and Forest Transition: Tunnelling through the Environmental Kuznets Curve, *Ecological Economics,* 79, 44-51.

[9]. Culas, R. J. (2009): The causes and consequences of tropical deforestation: a review. *International Journal of Climate Change: Impacts and Responses,* 1(2), 127-139.

[10]. Culas, R. J. (2008): Non-forest sector policies, global environmental markets and the deforestation process, in: Sanchez, I. B., Alonso, C. L. (Eds.), Deforestation Research Progress. Nova Science Publishers Inc, New York, USA. pp. 127-139.

[11]. Culas, R. J. (2007): Deforestation and the environmental Kuznets curve: an institutional perspective. *Ecological Economics*, 61, 429-437.

[12]. Culas, R. J. (2006): Debt and deforestation: a review of causes and empirical evidence. *Journal of Developing Societies,* 22, 347-358.

[13]. Damette, O., Delacote, P. (2008): The Environmental Resource Curse Hypothesis: The Forest Case, Working Paper. INRA-LEF.

[14]. Ewers, R. M. (2006): Interaction effects between economic development and forest cover determine deforestation rates. *Global Environmental Change,* 16, 161-169.

[15]. FAO (2010): Global Forest Resources Assessment, Progress towards sustainable forest management. FAO, Forestry Paper 163. Food and Agricultural Organisation, Rome.

[16]. FAO (2006): Global Forest Resources Assessment, Progress towards sustainable forest management. FAO, Forestry Paper 147. Food and Agricultural Organisation, Rome.

[17]. FAO (2000): Forest Resources Assessment, Food and Agricultural Organisation, Rome.

[18]. FAO (1995): Yearbook of Forest Products, Food and Agricultural Organisation, Rome.

[19]. Gullison, R, E., Losos, E. C. (1993): The role of foreign debt in deforestation in Latin America. *Conservation Biology,* 7, 140-147.

[20]. Houghton, R. A. (2005): Tropical deforestation as a source of GHG emissions. In: Moutinho, P., Schwartzman, S. (Eds.), Tropical Deforestation and Climate Change. Amazon Institute for Environmental Research and Environmental Defence, Brazil, pp.13-22.

[21]. Kahn, J. R., Mcdonald, J. A. (1995): Third-world debt and tropical deforestation. *Ecological Economics,* 12, 107-123.

[22]. Kant, S., Redantz, A. (1997): An econometric model of tropical deforestation. *Journal of Forest Economics,* 3, 51-86.

[23]. Karsenty, A. (2008): The architecture of proposed REDD schemes after Bali: facing critical choices. *International Forestry Review,* 10, 443-457.

[24]. Mather, A. (1992): The Forest Transition, Area 24, 367-379.

[25]. Pindyck, R. S., Robinfeld, Daniel L (1991): Econometric Models and Economic Forecasts, McGraw-Hill, Inc.

[26]. Rudel, T. K., Coomes, O. T., Moran, E., Achard, F., Angelsen, A., Xu J., Lambin, E. (2005): Forest transitions: towards a global understanding of land use change. *Global Environmental Change,* 15, 23-31.

[27]. Rudel, T. K. (1998): Is there a forest transition? deforestation, reforestation, and development. *Rural Sociology,* 63, 533-552.

[28]. Templeton, S. R., Scerr, S. J. (1999): Effects of demographic and related microeconomic change on land quality in hills and mountains of developing countries. *World Development*, 27, 903-918.

[29]. Tole, L. (1998): Sources of deforestation in tropical developing countries. *Environmental Management,* 22, 19-33.

[30]. UNCTAD (2001): Handbook of Statistics, New York and Geneva.

[31]. WCED (1987): Our Common Future. World Commission on Environment and Development. Oxford, University Press, Oxford.

[32]. World Bank (2000): World Development Indicators. World Bank, Washington DC.

[33]. WRI (various years): 1996-97, 1998-99, and 2000-2001, World Resources, World Resources Institute, Oxford University Press.

[34]. Yieridoe, E. K., Nanang, D. M. (2001): An Econometric Analysis of the Causes of Tropical Deforestation: Ghana, Selected Paper Presented at the American Agricultural Economics Association Conference, 5-8, August, Chicago.

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