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Forest Area Dynamics in Asia

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Abstract: This paper uses panel data methods to determine the impact of the level of human development, export of forest products, rural population density, and political and civil liberties on plantation, natural and total forest area in 20 Asian countries. Results on forest transition pattern are mixed. Level of human development and export of forest products tend to have significant effect on forests in pooled models. Evidence for positive export effect on forest plantations suggests key role of market incentives in channeling private and public investments in expanding forest plantations, forest carbon sinks and for sustainable forest management. Observed simultaneity of influence suggests further research on latent influences on forest area.

Key words: Forest dynamics, latent influences, forest sinks, forest regimes.

Preliminary

The linkage of country-specific structures can be a self-perpetuating process. Economic, social, political and cultural structures can cause serious environmental damage. But at one hand, existing state of development and internal structures of a country can also be influenced by environmental constraints. Despite the robust literature, not much consensus has been reached on the significant effect of mediating contributors to environmental issues such as air and water pollution, natural resource depletion (i.e. deforestation and forest decline), pollution of transboundary rivers, acid rain and global warming.

Multi-country studies on latent or underlying factors hypothesized to impact on those environmental issues and the nature of relationship existing among them, lack empirical regularity. Due to econometric techniques, explanatory variables specified in the model, data reliability (Bhattarai and Hammig, 2001; Palo, 1999), selected environmental quality indicators and time period, results are mixed. Further studies on the observed patterns of environmental transition and factors hypothesized to impact on the environmental condition triggered by within and across country structures are needed.

We explore latent influences on forest area variation such as country-specific level of human development, economic, demographic and institutional factors in 20 countries in Asia. We determine the impact of these latent factors on forest area from 1980 to 2000 by panel data method while accounting for heteroscedasticity and autocorrelation in the data sets. We also test for transition pattern between forest area and the level of economic development.

Renewed focus on forest area transition in Asia has risen from interesting results from previous empirical studies. Studies of tropical forest in Africa, Latin America and Asia, find evidence for an inverted-U shape relation between income per capita and the rate of deforestation in the said regions, with the exemption of Asia (Cropper and Griffiths, 1994; Koop and Tole, 1999). Asia also deviates from the hypothesized pattern in cross-national study of institutional characteristics and macroeconomic policy factors on deforestation (Culas and Dutta, 2002; Koop and Tole, 1999; Uusivuori et al., 2002). A revisit on the Asian case may illuminate understanding on the latent forces that influence the multi-dimensional character of forest area dynamics.

The paper starts with the current status of forests and cumulative carbon emissions due to land-use change in

Asia followed with a summary of the theoretical background on forest transition, latent variables and model specification used in previous studies on the changes in forest cover in various countries. It presents the variables and discusses panel data techniques before explaining the estimation model used in the analysis. The author reports the result from the estimation procedures and concludes with problems associated with cross-country regression analysis and suggestions for further extensions of forests transition models.

Forests in Asia

The Asian region covers approximately 700 million hectares of forests, around 17 percent of the world's total (ftp://ftp.fao.org), the largest proportion of which is in Southeast Asia. Although most countries in the region have around 20 percent forest cover, deforestation is still a major environmental problem (see Figure 1). Among the countries in this study, only Bangladesh, China, India and Vietnam register positive forests annual rate of change from 1990-2000.

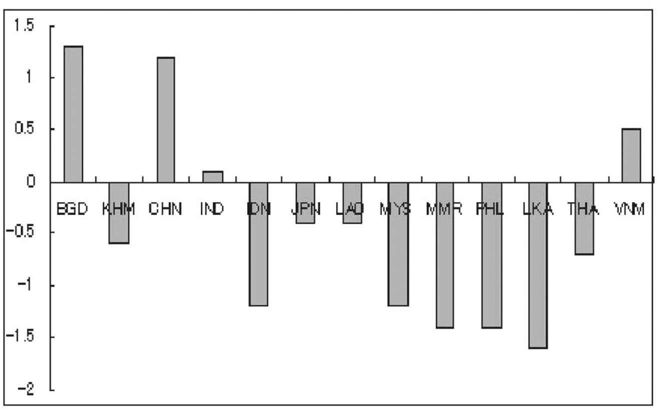

Figure 1: Deforestation rate (1990-2000).
***Source:* World Resources Institute, 2004**

Figure 2 shows the total mass of carbon dioxide (CO_2) absorbed or emitted into the atmosphere between 1950 and 2000 as a result of man-made land use changes (e.g. deforestation, shifting cultivation, vegetation re-growth on abandoned croplands and pastures). For countries with

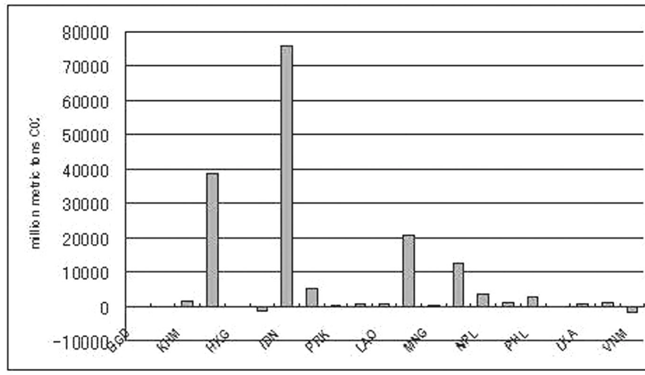

Figure 2: Cumulative emissions due to land-use change (1950-2000).
***Source:* World Resources Institute, 2004**

positive values indicate a positive net flux ("source") of CO_2; carbon dioxide has been released into the atmosphere as a result of land-use change[1] . Negative values indicate a negative net flux ("sink") of CO_2; in these countries, carbon has been absorbed as a result of the re-growth of previously removed vegetation. As seen in Figure 1, only countries undergoing afforestation (positive deforestation rate) and reforestation, namely Bangladesh, India and Vietnam, have favourable performance in cumulative emissions from land use. Countries with high deforestation rates like Indonesia, Malaysia and Myanmar, are also heavy emitters of CO_2 from land use from 1950 to 2000 (Table 1). Although majority of global CO_2 emissions are from burning of fossil fuels, roughly a quarter of the carbon entering the atmosphere is from land-use change and thus, along with CO_2 from fossil fuels and other greenhouse gases, constitute as the main sources contributing to climate change.

Forests are designated as natural, plantations, or mixed/semi-natural based on a combination of Forest Stewardship Council (FSC). To manage these forest-types, an international system of certification of sustainable forest management is operational in Asia. In 2004, 470,000 hectares of forest lands are FSC-certified in Asia[2] . Majority of the countries under study have yet to adopt a national certification scheme and are in the process of development and implementation of criteria

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[1] Data include emissions from living and dead vegetation disturbed at the time of clearing or harvest, emissions from wood products (including fuelwood), and emissions from the oxidation of soil organic matter in the years following initial cultivation. Those ecosystems that are not directly affected by human activities such as agriculture and forestry are not included in these estimated sources and sinks.

[2] WRI compilation of data from: Forest Stewardship Council (FSC) 1998, 1999, 2000, 2002, 2004. Forests certified by FSC-Accredited Certification Bodies. Document 5.3.3. Available online at: http://www.fscoax.org/principal.htm. Certification is awarded by Forest Stewardship Council (FSC)-accredited groups around the world to assure purchasers that forests are managed within each country's legal framework. WRI has compiled data from these periodic updates to cover a five-year time span.

Table 1: Cumulative emissions from land use (1950-2000) Region/Country

Region/Country		*CO_2 in million metric tonnes*
Asia		**163620.9**
Bangladesh	BGD	-273.4
Bhutan	BTN	0
Cambodia	KHM	1658.2
China	CHN	38909.4
Hong Kong	HKG	11.7
India	IND	-1191.1
Indonesia	IDN	75740.5
Japan	JPN	5007.8
Korea, Dem People's Rep	PRK	313.5
Korea, Rep	KOR	867.2
Lao People's Dem Rep	LAO	698.1
Malaysia	MYS	20654.1
Mongolia	MNG	69.1
Myanmar	MMR	12570.9
Nepal	NPL	3648.4
Pakistan	PAK	1291.6
The Philippines	PHL	2803.4
Singapore*	SGP	0.7
Sri Lanka	LKA	873
Thailand	THA	1407.5
Viet Nam	VNM	-1439.5

Source: World Resources Institute (WRI), 2003. Report to the WRI from the Woods Hole Research Center. Available on-line through the Climate Analysis Indicator Tool (CAIT) at http:/cait.wri.org.

*Cumulative emissions from 1988-2000 only.

and indicator of sustainable forest management. Within the region, Japan has the widest FSC-certified total forests area with 266,486 hectares followed by India and Malaysia with 90,240 and 77,242 hectares, in 2004, respectively.

Phenomenology of Forest Area Dynamics

Environmental Kuznets Relations

Environmental quality transition exhibits a pattern very much similar to a bell-shaped pattern between growth in per capita income and income inequality. This pattern is graphically depicted as the Environmental Kuznets Curve (EKC), a slight modification of the Kuznets curve. Yandle et al. (2002), in a primer on EKC, notes that in 1991 the Kuznets curve was used to describe the relationship between environmental quality and per capita income across time. Empirical evidences on the existence of EKC, initially on sulfur dioxide emissions and other air pollutants (Seldon and Song, 1994), and later on to deforestation (Koop and Tole, 1999; Palo, 1999; Palo, 2003), show that the same inverted U-pattern exists. The advent of the EKC became the precursor of expanding research on the systematic linkage among human development, economy and the environment.

Empirical analyses on the EKC have focused predominantly on the existence of the inverted U-pattern and on the turning point, the per capita income threshold at which environmental quality begins to improve (Barbier, 1997; Yandle et al., 2002). These analyses have resulted in policies which usually increase the level of income in developing countries, to curb environmental damage. Attempts to avoid such damages in the early stages of development are futile. Moreover, it implies that environmental quality exhibit qualities similar to a luxury good at higher level of income (Ruttan, 1971; Yandle et al., 2002). A country begins to give due consideration to human development and its environmental dimension only when an income threshold suggested by the EKC thesis has been reached. A similar environmental transition hypothesis reflecting the trade-off between environment and economic development is developed by Antle and Heidebrink (1995). However, transition to an environmental stage is much more complex than mere economic relations. Underlying and mediating factors that predispose such transition has to be considered. The succeeding subsection presents a synopsis of existing economic models of deforestation and the emerging literature of forest transition theory.

Economic Models of Deforestation

Early 1990s witnessed the emergence of economic models constructed to provide explanation as to why deforestation and forest transition happen. The multidimensional process involved in forest area decline and degradation has been simplified to establish causal relationships and the quantitative effects of exogenous variables involved in the process. According to Hirsch (1999), the mode at which deforestation is explained ranges from (1) regression analysis based on local and global data and the hypothesized factors of deforestation; (2) structural analysis that deals with analytical connection of the ultimate causes to proximate factors and; (3) historical analysis of the changes in forest and how this resource is utilized. However, existing multi-country economic models explaining deforestation can be clustered into two general types: (1) direct causes or the immediate causes and (2) the indirect causes of the underlying factors of deforestation and forest variation.[3]

The first type of global economic models focuses on the agents of deforestation. It supposes that agents' actions are the primary or immediate cause of forest cover loss. The identified agents in these models are the small farmers, ranchers, loggers etc. and their actions relative to forest clearing. A literature review conducted by Kaimowitz and Angelsen (1998) identified three main activities at which these agents have contributed to deforestation in developing countries: logging, agricultural/pastoral encroachment and fuelwood collection. Studies identify logging as the proximate cause for unsustainable deforestation in most regions of Asia and Latin America (Anderson, 1989; Repetto, 1990).

According to Palo (2003), local economic agents are responding to impetuses such as attaining subsistence and profit maximization, and are only behaving in accordance with economic incentives from national and international market structures and policies. There are underlying structures which acts as predisposing conditions, contextual and background factors of forest cover loss (Hirsch, 1999; Uusivuori et al., 2002). Underlying structures are related to societal, economic, political, demographics and ecological contexts in which changes in forest area or deforestation occurs. These underlying or latent factors seem to be linked in a complex and intricate web of interaction and feedbacks through institutions (markets and political processes) resulting in significant influences on forest cover. This chain of causation makes identification of causality links a difficult exercise.

Empirical research on several mediating and underlying factors from demographic (Bhattarai and Hammig, 2001), ecological (Uusivuori et al., 2002), distributional (Koop and Tole, 1999), institutional and policy-interventions of the government (Anderson and Reis, 1997; Bhattarai and Hammig, 2001) and economic influences (Andreoni and Levinson, 2001; Koop and Tole, 1999) on deforestation and the state of forest is robust. Researches suggest that the relationship between social goals, particularly economic growth and human development, and environmental quality manifests trade-off and patterns of transition (Andreoni and Levinson, 2001; Cropper and Griffiths, 1994; Koop and Tole, 1999). The government through its policy-interventions, reluctance to deal with institutional changes and corruption, is also cited as culprit to damages to the environment (Anderson and Reis, 1997; Bromley, 1999; Meyer et al., 2003; Palo, 2003). In this sense, environmental problems like forest decline are multi-faceted and are outcomes of complex combinations of fundamental forces of market failure, policy-interventions and internal structures inherent in a society. Internal states of a society particularly, poverty and inequality conditions, were also seen as pressures on the environment (Cavendish, 1999; Ekbom and Bojo, 1999; Shyamansundar, 2002). Thus, a one-dimensional approach to understanding environmental issues can be misleading and limiting.

Forest Transition Theory

Forest transition theory shares similar thesis with Environmental Kuznets Curve. It also posits nonlinear transition in forest cover during the course of transition in economic activities, resource use and demographic factors (Perz and Skole, 2003). This transition pattern in forest cover is a mirror reflection of the inverted U-shaped EKC. Studies of Drake (1993), Mather (1992) and Walker

[3] For an in-depth and detailed analysis of existing economic models of deforestation, refer to Kaimowitz and Angelsen (1998). 150 models of deforestation in the tropics were selected and reviewed according to modes and structural approach to the various influences to forest cover loss.

(1993) reveal that due to deforestation, forest cover initially declines but at some point, forest cover loss is outweighed by new forest expansion that paves way for improved forest cover. Among the expanding body of researches on forest transition theory are that of Koop and Tole (1999), Mather (1992), Matcher and Needle (1998) and Rudel (1998). These multi-country analyses focus on member-countries of the Organization for Economic Cooperation and Development (OECD). Although a significant number of cross-country analyses in the regions of Africa, Latin America and Asia exist, analyses are on tropical deforestation. On the other hand, studies of Vincent et al. (1997) in Malaysia, Rigg (1993) in Thailand, and Puerto Rico (2000) deal with nonlinear forest dynamics.

Uusavory et al. (2002) while controlling for population, income and ecological conditions, reported further empirical evidence for the existence of a U-shaped distribution among 67 tropical countries. Palo (2003) measured the relationship of forest and poverty using two leading indicators of economic development: GDP/capita and the Human Development Index (HDI) by the United Nations Development Program (UNDP). Regressing total forest area (natural plus forest plantation) and GNP/capita, the study finds empirical support for a U-shaped distribution in 166 countries. Substituting GDP/capita with HDI, the study reveals that low levels of economic development or increase in poverty is associated with decline in relative forest area. These findings lend empirical support to forest transition paradigm given levels of economic development. Further, Palo (2003) also reports that poverty and forest correlation is evident in 17 countries in Asia and notes on the prospects of poverty reduction through commercialization of forest services such as ecotourism, biodiversity and carbon sequestration. However, the variability of these options requires further theoretical and applied research.

There are issues arising from studies on the forest transition theory. In Perz and Skole (2003), theorizing should include various types of forest cover and its ecological and economic characteristics, the details about the nature of transition, and social forces that catalyze the transition. Their study finds biophysical impediments and social obstacles such as limited land settlement, low incomes, urbanization, and shift in agricultural activities result in the secondary forest expansion in the Brazilian Amazon. They suggest refinements of the theory to account for land cover changes. Perz and Skole (2003) also call for model development for the forest transition dynamics and researches covering non-members of the OECD. Further empirical research on forest transition dynamics should therefore address underlying factors that influence and expedite conditions leading to the initial decline due to deforestation, then forest expansion, and eventually forest recovery.

Variables and the Econometric Models

The empirical exploration of forest area variation in Asia includes 20 countries and controls four variable categories: (1) level of human development; (2) economic; (3) demographic; and (4) political institutional variables.

Variables

Defining Forests

We adopt Food and Agriculture Organization (FAO)'s definition of forests. Total forest area, measured in thousand hectares (ha), is an area of land over 0.5 hectares with tree density of at least 10 percent (or equivalent stocking level). This definition invokes forests as determined both by trees and the absence of other predominant land uses, and are composites of natural forest and forest plantations. The term particularly excludes fruit tree plantations and other tree stands established purposively for agricultural production and trees planted in agro forestry system (FAO, 2000a)[4]. Natural forests are composed of indigenous trees and are not classified as plantations. On the other hand, forest plantations are established by planting or/and seeding in the process of afforestation and reforestation[5]. It consists of introduced species and in other cases indigenous species (FAO, 2000b). In the 1996 FAO's assessment of forest resource, forest area, unlike forest area change (an alternative deforestation indicator taken in two successive

[4] Due to lack of data for some countries, FAO constructs estimates using various methods such as the so-called convergence of evidence. Issue on data reliability of FAO estimates is raised. To adhere to better data reliability, this paper uses forest area figures regularly collected from a minimum of five years to a maximum of ten years. Trend estimates are usually published by FAO every two years.

[5] Afforestation is the change in forest area due to conversion from other land uses into forests resulting in an increase of the canopy cover to the 10 percent defined threshold of forest (FAO, 2000b). Reforestation refers to re-growth of forest after a temporary (less than 10 years) condition with less than 10 percent canopy cover due to human induced or natural perturbation (ibid).

accountings), yields higher data reliability. Further, forest area change, aside from sampling theoretical handicap, suffers from discrepancies in the definition, classification, observation methods and implementation thereby reducing data reliability (Palo, 1999).

Latent Influences

Widely accepted theoretical framework for underlying determinants of changes in forest area, from a phase of deforestation and then to forest recovery, is yet to exist. Significant underlying forces of declining environmental quality may vary from country to country and region to region. We utilize variables found to be associated with pressing environmental issues both in previous empirical studies and in theoretical explorations, in estimating the latent factors of forest area dynamics. The variables incorporated in the investigation are institutions, economic, demographic, and the level of human development within a country.

Low levels of economic development or the existence of poverty is often cited as a predisposing condition of environmental damage. Raising the standard of living and other development efforts in a country have been hypothesized to be achieved with environmental costs. Loss in forest cover is caught in the vicious cycle of poverty and environmental destruction (Palo, 2003). In contrast with previous forests transition studies and models, Human Development Index (HDI) of the United Nations Development Programme (UNDP), an alternative measure to Gross Domestic Product per capita, is used as a measure of economic development .It is hypothesized that a country's desire to achieve higher level of human development can exert negative pressure on forest as a natural resource. HDI is a composite index that measures a country's achievement in three basic aspects of human development: longevity, knowledge and a decent standard of living. Longevity measures life expectancy. Knowledge considers people's acquisition of skills and knowledge (measured by mean years of schooling (one-third weights) and adult literacy (two-thirds weight). Level of living is measured in terms of purchasing power based on real Gross Domestic Product (GDP) adjusted for local cost of living (purchasing power parity) (UNDP, 2003).[6]

Our proxy variable for political-institutional structures is an average sum of political and civil liberty indices from Freedom House datasets[7] .The political-institutions index ranges from one to seven values, where a lower average indicates greater political and civil liberties[8] . The political rights index (with values 1-7) measures rights to participate meaningfully in the political process. A high-ranking country in this index is likely to decentralize power; there is absence of foreign domination and a consensus that allows the population to exercise some power. The index of civil liberty (with values 1-7) measures the extent at which people are able to express their opinion openly, organize and participate in civil activities such as demonstration. It also reflects freedom of religion, education, and other personal rights. These indices measure political and civil freedom, 7 being a country with least freedom and 1 with the highest scale of political and civil freedom. The cardinal measure of the index allows quantification of the marginal impacts of improved institutional factors, acting as social capital on the deforestation process (Bhattarai and Hummig, 2001).We expect that improvement in institutions will have favourable effect on forest area. Further, the extent at which the people are empowered signifies their influence on the context within which environmental governance[9] is constituted and implemented, and how they hold the government, corporate authorities and agents responsible for environmental problems.

Demographic pressures are often cited as major driving forces to forest cover loss. Existing global and regional regression models used total rural and urban population and their densities and growth to reflect demand for agricultural and forest products. Rural population density

[6] Methodological underpinnings of the HDI are straightforward and appear as a technical note to the various Human Development Reports. Pollution sensitive-HDI is currently being developed by the United Nations Development Programme to respond to the critique that this index does not reflect the environment dimension of human development and efficiency of resource utilization.

[7] Freedom House is non-profit and non-partisan organization for democracy and freedom worldwide, established for more than 60 years.

[8] The use of this index is adapted from an empirical study conducted by Bhattarai and Hammig (2001) on institutions and the EKC for deforestation. Shafik and Bandyopadhyay (1992) also explore the impact of political and civil liberties on environmental quality. Unlike Bhattarai and Hammig (2001), they report no significant effects on clean water and sanitation but higher values on these indices are associated with greater deforestation. Also, more democratic countries are associated with higher levels of sulfur dioxides but no clear association with carbon emissions. However, results for political and civil liberties indicate no clear pattern.

[9] Environmental governance refers to the manner at which formal and informal institutions, and the constituents in a society respond to environmental issues (Pas-ong and Lebel, 2000).

(rural population density divided by total arable land) reflects pressure exerted on forest resources for: (1) fuelwood energy and (2) in attaining food and livelihood security, particularly on households settling in the rural area. It also reflects the effects of direct agents of deforestation (Palo et al., 1996).

We incorporate the value of forest product exports to determine the pressure exerted by trade of forest products on forest area. Forest product export covers aggregates of forest products such as industrial roundwood, fuelwood and charcoal, sawnwood, wood-based panels, wood pulp, and paper and paper board (including newsprint, printing and writing paper and other paper and paper board products).

The Econometric Models

In investigating latent factors affecting forests, we draw panel data from 20 Asian countries from periods 1980, 1990, 1995 and 2000. Panel data method accommodates cross-country heterogeneity and allows for identification of country-specific effects on global or cross-country regression studies. It allows for larger data points, which aid in increasing the degrees of freedom and reducing collinearity among the explanatory variables. With larger data points, efficiency of econometric estimates is improved (Baltogi, 1995; Hsiao, 1986). The basic OLS (Constant-intercept-and-slope) model in most studies empirically testing the existence of EKC for deforestation implicitly assumes commonality of structure among countries. That is, the effect of the explanatory variable on the dependent variable (in this case forest area) is the same. Thus, it does not allow for country-specific inferences. However, this form has been useful in determining simple stylized patterns among countries (Koop and Tole, 1999).

Basic OLS for panel data can be generalized to allow for omitted variables that are specific to individual cross-sections (in this case, country-specific), but are time-invariant and the effects which are time-specific but are cross-section invariant to enter in the estimation. The error term from this unrestricted panel model represents unobserved country-specific and time-invariant effects. This unrestricted panel model is referred to as the fixed-effects model. Hsiao (1986) presents the fixed-effects (FE) model in vector of dummy variables. The dummy variables for unobserved country-specific (and/or period-specific) effects are not included in the estimation of coefficient in the FE model. Individual observations are measured as deviations from individual means over time. This model regards unobserved effects as country-specific but stay constant overtime. In a sense, these are within-country variances that can be attributed to inherent socio-economic, political or ecological structures. In econometrics, FE models are referred to as analysis of covariance model since they take into account both the quantitative effects of the parameters in the regression and the qualitative effects within the cross-section variation (Hsiao, 1986).

Random-effects (RE) model or the variance component model is similar with the fixed-effects model. Only, the error term is joined by country-specific effects which now act as a random variable rather than a fixed constant. The error term is composed of country-specific effect and time-specific effect and the usual stochastic disturbance. Unobserved country-specific effects are mutually independent and not correlated to the explanatory variables in the estimation (Battagi, 1995; Greene, 1997; Hsiao, 1986). In cross-country regression studies, omitted variables can have country-specific and period-specific effects that can be peculiar to individual countries, time period or in both. Since the RE model allows these effects to be random, the errors are correlated. We can arrive at a BLUE estimate for the slope parameters using the Generalized-Least-Square (GLS) method[10] . GLS estimator is a matrix of weighted average of within-and between-units estimators.

Fixed and random effects model allow for country-specific variations but still retain the restrictive assumption of commonality of structures across countries. This means that although these models allow for specific differences into the estimation, same functional form in every country is expected (Greene, 1997). Since we are interested in country-specific effects, we use these models to allow for better empirical exploration of the impact of economic, institutional, demographic factors and the level of human development on forest area in Asian countries.

The Estimation Model

We specify the general form of the reduced form empirical model of forest area dynamics as follows:

$$F_{it} = \alpha_i + \beta_1 HDI_{it} + \beta_2 itHDI^2 + \beta_3 INST_{it} + \beta_4 EXPRT_{it} + \beta_5 RPDEN_{it} \quad (8)$$

[10] For detailed discussion on the econometrics of Generalized Least Squares (GLS) refer to Hsiao (1999), Baltagi, H. (2000), Wooldridge, J. (2001) and Madala, G. (2001).

where, $i = 1, ..., n$ Asian countries and t = years; F_{it} is the forests (total, natural and plantation) measured in thousand hectares in country i, year t; α_i the intercept term for country i; β_i the coefficients to be estimated; HDI_{it} the Human Development Index; $INST_{it}$ the institutional index; $EXPRT_{it}$ the export of forest products; and $RPDEN_{it}$ is rural population. The linear specification of all the variables provides results that can be interpreted directly as correlations, except for the quadratic term of the HDI variable to validate the pattern described in forest transition literatures. We estimate parameter values using simple pooled regression, as well as FE and RE models. Test for poolability supports adopting constant parameter estimates of forest area overtime and across countries[11]. Total forest area and natural forest area estimation included 20 Asian countries while 19 countries for forest plantations[12]. However, solely adopting pooled models can be limiting in inferring on forest area variation across and within-countries. Thus, the assumption of homogeneity across-countries is relaxed to accommodate diversity of economic, social, political, ecological and other internal structures within countries. Statistical tests are shown in Tables 2, 3, 4 and 5.

RE model is favoured over the FE model by the Hausman test statistic[13]. This implies that country-specific effects are treated as random disturbances just like the usual stochastic disturbance u_{it}. The intercept α_i captures this group-specific disturbance that affects each country more or less equally. Analysis of variance components model (RE) also implies that country-specific and period-specific effects tend to influence the variation in average forest area from 1980 to 2000 in Asia. To address heteroscedasticity and autocorrelation, we use White's Heteroscedasticity-Consistent Covariance[14] and Cochrane-Orcutt[15], respectively.

Table 2: Latent influences on forest plantations variation

Variables	*Pooled OLS*[a]	*Cochrane-Orcutt Method*[b]	*FE Model*[a]	*RE Model*
Constant	$-1.13 \times 10^{5***}$	-8.13×10^{3}		–17549.6
HDI	$-1.97 \times 10^{5***}$	2.22×10^{4}	$1.11 \times 10^{5***}$	–6704.21
HDI^2	$3.00 \times 10^{5***}$	-1.37×10^{4}	-1.19×10^{5}	29231.13
Institution	212.96	198.74	-445.99	-225.40
Export Value	0.0033^{**}	0.0001	0.0016^{**}	0.0022^{*}
Rural Population Density	310.09	-50.59	595.55	408.74
Adjusted R^2	0.1758	.7911	0.7952	0.7947
F-statistic	3.73^{*}		11.81^{*}	
Durbin-Watson Statistic	0.3944	2.86	1.70	1.32
ρ Estimate Range		–0.14 to 2.48		
Hausman Statistic	$\chi^2 = 4^{NS}$			
Poolability Test	$\chi^2 = 206.67^{*}$			
Forest Transition Pattern	U-shaped	Inverted U-shaped	Inverted U-shaped	U-shaped

[a] Estimation is based on White Heteroscedasticity-Consistent Standard Errors and Covariance
[b] Corrected for First-Order Serial Autocorrelation
*significant at $\alpha = .01$; **significant at $\alpha = .05$; ***significant at $\alpha = .10$

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[11] The likelihood ratio tests for equal variances (poolability) in the cross-sections under the general assumption $u_{it} \sim (0, \Omega)$. It is a chi-square with degrees of freedom $(N - 1) K'$. Baltagi (2000) presents a proof on how this ratio can be based from Chow F-statistic.

[12] Due to lack of complete information on forest plantations from FAO (the major data sources of measures of forest area used in the analysis, for some period) Japan is excluded in the estimation.

[13] The Hausman test resulted in a statistically insignificant χ_2. This implies that we cannot reject the null hypothesis that the unobserved effects are uncorrelated with the explanatory variables, $E(u_{it} | X_{it} = 0)$. In this case, the random-effects estimator is consistent and efficient. Fixed-effect estimator is consistent but not efficient. This result is inconsonance with Mundlak (1978) suggesting that u_{it} should be treated as random.

[14] Whites's Heteroscedasticity Consistent Estimate (WHCE) is a variance estimator which is robust to heteroscedasticity within each cross-section but not for contemporaneous correlation across-sections.

[15] This technique corrects for first-order serial correlation in the panel data. It tests whether autocorrelation is the same or different in the cross-section.

Table 3: Latent influences on natural forest variation

Variables	*Pooled OLS*[a]	*Cochrane-Orcutt Method*[b]	*FE Model*[a]	*RE Model*
Constant	$-4.38 \times 10^{5***}$	-2.69×10^{4}		–1647.94
HDI	$-8.53 \times 10^{5*}$	1.16×10^{5}	3.45×10^{4}	-8.84×10^{4}
HDI^2	$1.24 \times 10^{6*}$	-1.21×10^{5}	-6.32×10^{4}	1.01×10^{5}
Institution	1645.07	1617.19	1168.13^{***}	1202.02
Export Value	$.0211^{*}$	0.0144^{***}	–0.0023	-4.68×10^{-5}
Rural Population Density	143.27	268.98	$-1.15 \times 10^{3***}$	–1112.69
Adjusted R^2	0.5789	0.9837	0.7952	0.9712
F-statistic	19.42^{*}		169.36^{*}	
Durbin-Watson Statistic	0.7508	2.10	1.70	0.6719
ρ Estimate Range		–0.25 to 1.85		
Hausman Statistic	$\chi^2 = 4^{NS}$			
Poolability Test	$\chi^2 = 216.71^{*}$			
Forest Transition Pattern	U-shaped	Inverted U-shaped	Inverted U-shaped	U-shaped

[a]Estimation is based on White Heteroscedasticity-Consistent Standard Errors and Covariance
[b]Corrected for First-Order Serial Autocorrelation
*significant at $\alpha = .01$; **significant at $\alpha = .05$; ***significant at $\alpha = .10$

Table 4: Latent influences on total forest variation

Variables	*Pooled OLS*[a]	*Cochrane-Orcutt Method*[b]	*FE Model*[a]	*RE Model*
Constant	$-4.48 \times 10^{5**}$	-1.45×10^{4}		14299.17
HDI	$-8.58 \times 10^{5*}$	7.94×10^{4}	1.10×10^{5}	-7227.27
HDI^2	$1.26 \times 10^{6*}$	-9.39×10^{4}	-1.44×10^{5}	11665.66
Institution	820.94	1527.34	514.44579	1202.02
Export Value	$.0237^{***}$	$.0148^{*}$	.0001	.0016
Rural Population Density	365.93	543.65	-43.19	-101.132
Adjusted R^2	.4984	.8378	.9804	.9741
F-statistic	14.71^{*}		145.148^{*}	
Durbin-Watson Statistic	.4630	2.12	1.26	1.30
ρ Estimate Range		-0.05 to 2.14		
Hausman Statistic	$\chi^2 = 4^{NS}$			
Poolability Test	$\chi^2 = 230.40^{*}$			
Forest Transition Pattern	U-shaped	Inverted U-shaped	Inverted U-shaped	U-shaped

[a]Estimation is based on White Heteroscedasticity-Consistent Standard Errors and Covariance
[b]Corrected for First-Order Serial Autocorrelation
*significant at $\alpha = .01$; **significant at $\alpha = .05$; ***significant at $\alpha = .10$

Results and Discussion

The results of the estimation of the latent influences on forest plantation, natural and total forest area dynamics in Asia are given in Tables 2, 3, 4 and 5. We begin this section with a discussion of the forest transition pattern exhibited in the countries drawn for this analysis and then on the simultaneity of influence of the latent factors on plantation, natural and total forest area variation.

Forests and Human Development

The signs of the estimated HDI coefficients from pooled OLS and RE models reveal a U-shaped transition for plantations, natural and total forest area. The result supports the pattern described in existing forest transition literatures. Level of human development within the countries significantly influence forest area over the span of twenty years when the assumption of homogeneity is imposed. Although this significance is not validated in

Table 5: Institutions and forest area

Variable	*Plantations*	*Natural forests*	*Total forests*
Constant	18509.2624	-62055.9351	-32013.28619
HDI	67530.9430	–257095.4831	–153759.8143
HDI^2	-70060.2703	317461.8333	193784.1576
Export Value	0.0021**	0.0040**	0.0050***
Rural Population Density	242.5905	–1347.3159***	–1088.3306***
Country		INST Coefficient	
Bangladesh	-1417.493032	-8202.8341	-3262.9111
Bhutan	-732.2508502	-2399.4177	-967.89167
Brunei	-2343.1550	587.1010	-254.7751
Cambodia	-660.2072	–3214.9299***	-1243.8850
China	3220.3337**	13485.1940*	9259.2148*
India	2669.1542***	4795.4744*	4749.9473*
Indonesia	-2005.4910	16389.5190*	7996.6300*
Korea, DPR	-1713.0518	-1611.0334	-872.1067
Korea, Rep	-2271.6633	-1020.9702	-880.6579
Laos	-468.4422	-2544.8539	-866.2158
Malaysia	–2655.6990*	-1906.8751	-1130.7252
Mongolia	-1157.2352	-3206.3277	–1375.3935***
Myanmar	-443.1623	-50.7188	418.0815
Nepal	-1013.6572	–6059.0418**	–2365.9351**
Pakistan	-525.4052	–6123.2964**	–2446.0653*
The Philippines	-3007.7236	-3831.0057	-1984.3578
Sri Lanka	-2241.6972	-3038.8044	-1607.0596
Thailand	-2342.3077	-2496.9326	-1069.1250
Vietnam	-888.1992	-1272.4407	-471.5396
Japan	—	5350.8166	2975.465595
R-squared	0.8378	.9687	.9788
Adjusted R-squared	0.7469	.9498	.9675
S.E. of regression	4537.33691	7477.793	6817.8845
Sum squared residual	844084475.7	2.409	2.198
F-statistic	9.21*	53.88*	86.66*
Durbin-Watson stat	1.62	3.11	1.96

*significant at $\alpha = .01$; **significant at $\alpha = .05$; ***significant at $\alpha = .10$

the RE model, allowing for country-specific effects to enter the regression improves adjusted R^2. When unobserved internal structures within countries are treated as stochastic, about 79 percent of the variation in forest plantation, and 97 percent of average natural and total forest area are explained. The pattern implies that forests in Asian countries for the past 20 years since 1980 has undergone a period of deforestation (declining forest area) to a stage of recovery. The same U-shaped distribution is observed by Palo (2003) using GDP per capita and total forest area. The study also found a strong statistical correlation between high poverty (measured by HDI) and low relative forest area in 17 Asian tropical countries. Regressing forest area and HDI also aligns with the image proposed by the forest transition theory for pooled OLS and FE models. However, these regression models only explain a small proportion of the variations in forest area. Only significant evidence is found for FE and pooled OLS models.

A mirror image of the forest transition pattern described above is given by Cochrane-Orcutt, a pooled regression estimate corrected for first-order serial autocorrelation, and the fixed-effects (FE) methods. Although statistically insignificant, the sign of the linear and quadratic terms for Asia supports the environmental transitional hypothesis described in Goklany (1999) and the EKC for deforestation (Koop and Tole, 1999). The HDI coefficients suggest that at rising levels of human development, forest area tends to statistically increase. However, as HDI increases, forest area manifests signs of decline. At that HDI value, countries are estimated to be experiencing medium level of human development[16]. The increasing and then decreasing pattern in forest area reflects how forest is utilized as a resource in achieving higher level of human development. However, efficiency issue in forest resource utilization has to be dealt with in a separate study.

Although the various models used to describe behavioural patterns in plantations, natural and total forest area improve when heterogeneity in the data set is considered, no consensus on the pattern is achieved. Assuming homogeneity among countries results in declining forest area at low levels of human development. Inverted U-shaped pattern appears with the influence of the latent determinants on plantation, natural and total forest area in FE model and Cochrane-Orcutt method.

Latent Influences on Forest Area Variation

There is no widely accepted framework for theorizing underlying or latent influences to forest area dynamics or variation. Hence, establishing a direct linkage between them is far from simple. Quantitative relationships generated from our analyses are interpreted not as causal relations but rather associations. The results are, however, useful in inferring into the direction of the impact of mediating forces, acting independently or simultaneously, on forest area in Asia. Results reveal significant evidence for the level of human development and export of forest products on changes in forest area in Asian countries.

Export Value of Forest Products

The a priori expectation that a country's reliance on forest products for generating economic activity and foreign exchange would have adverse repercussion on the natural and total forest cover is not supported by the sign of the coefficients generated from the various models. The study found a significant positive correlation between forest area within-countries and export of forest products. This observation is common in developed countries where reliance on forest exports lead to increases in forest area, given sufficient amount of public and private investment, and people's participation in the preservation, conservation and regeneration of forests. Often cited examples are Finland and Sweden.

Wilson et al. (1998) found that despite being an important export sector, investment for financial and non-financial gains in forest generation occurs. Palo (2003) suggests that private property rights had been instrumental in generating investment flows to the forestry sector and have found empirical support for the vital role of private property rights in a U-shaped distribution between total forest area and per capita income. Moreover, the panel analysis provides a strong statistical correlation between the expansion of forest plantation in Asia and increasing value of forest product exports. This suggests that rising earning potentials from forest product exports tends to encourage private and public investments to be channeled to forest plantations. This lends empirical support to the key role of market-incentives in facilitating sustainable forest management and expansion of forest plantations. Moreover, potential use of forests as carbon sinks offers market opportunities for countries in future carbon trading and possibilities for carbon offsets, particularly with countries like Indonesia and China, registering with high carbon emissions estimates (Refer to Figure 2 and Table 1).

Negative correlation between forest product exports and natural forest area is generated from FE and RE models. Although statistically insignificant, this negative association is similar with the results obtained from other studies in countries like the Philippines, Thailand, and Indonesia (Kaimowitz and Angelsen, 1998; Panayotou and Sungsunian, 1994).Trade expansion in these countries have resulted in higher deforestation levels (Kaimowitz and Angelsen, 1998). Several trade and commodity models for forest cover clearing also find link between production of exportable forest products and loss in forest cover. Those studies incorporate export prices, income and population as principal explanatory factors in the models (ibid). Since, we only have significant positive trade effect, particularly from pooled OLS and Cochrane-Orcutt method, we take this interpretation with caution.

Rural Population Density

Rural population density is interpreted as an agent that exerts pressure on forest area for purposes of agricultural expansion (Angelsen, 1999). Studies (Myer, 1992; UNEP,

[16] Most of the countries in this study, with the exemption of Japan and South Korea, are classified by UNDP as countries with medium level of development in the longevity, education and income components of HDI. The UNDP ranks countries according to HDI indices and classifies countries into low, medium and high levels of human development. Japan, Brunei Darussalam, South Korea and Singapore are classified as countries with high level of human development, having an index value between 0.80 and 1.0. At the other end of the classification are Bhutan and Pakistan.

1992) find that the share of agricultural expansion on forest clearing is at least 50 percent. Population effects in countries may have varying impacts depending on circumstances at which population as an explanatory variable is interpreted. Allowing for country-specific effects in the estimation, FE and RE models result in negative rural population density coefficients for natural and total forests. This result supports the a priori expectation of negative rural population density effects. However, we only observe significant negative coefficient in natural forest cover. Estimates from other models suggest that increasing rural population density posts no threat to forest cover in Asia. A review of existing studies on demographic effects on deforestation concludes that quantitative effects remain indeterminate (Brown and Pearce, 1994; Kaimowitz and Angelsen, 1998). We note that existing spurious results on the relationship between population and forest cover further suggest that there maybe other factors that affects such relationship simultaneously. In a study on forest decline in Indonesia, population-effect is found to be acting in conjunction with a host of other explanatory factors, fixed or random in nature, making straightforward identification of quantitative relationships complex (Sunderlin and Resosudarmo, 1999).

Institution

Estimate for institutional influence for within-country forest variation in Asia provides positive coefficients for most of the models. We find significant positive correlation between natural forest cover and institutional index in the FE model. This association suggests that despite a country's low performance in political rights and civil liberties, declining forest area is not observed. Along with other parameters considered in the study, the average value of political and civil rights indices is positively correlated with widening forest area. Institution parameter does not support previous studies of Uusivuori et al. (2002), Deacon (1994) and Didia (1997) but conforms to the results of Mainardi (1996). See Table 5.

When institution parameter is allowed to vary in each country, lesser political and civil liberties were associated with lower forest area[17]. Table 5 shows significant negative correlation between natural forest and political and civil liberties in Nepal, Pakistan and Cambodia. Moreover, it reveals that Bhutan's total forest area falls with greater values of the institution parameter. Only China, India, Indonesia, Myanmar and Japan show positive forest area variation. Total forests, natural and plantation forests in these countries tend to increase with less political and civil liberties. Among those countries, only China, India and Indonesia have statistically significant evidence for such positive correlation in natural and total forests area estimates. For forest plantations, only India and China. Country-specific environmental governance can account for such positive correlation in these countries.

Simultaneity of Influence

Estimates from the variance components (or RE) model suggest that there are unobserved factors operating simultaneously with parameters that muddles the quantitative relationship between forest area and the latent influences covered in this study. Country-specific, period-specific or both, tend to have negative impact on forest area variation. With the exemption of five countries out of the 20 cross-section units considered in this panel study, random-effects collectively cause forest area in Asia to decline. Only China, India, and Indonesia tend to have favourable plantation, natural and total forest area from 1980 to 2000. Myanmar's natural forest and total forests are found to be positively influenced by unobserved country-specific effects. These uncaptured influences are also found to positively influence Japan's natural forest cover. An in-depth analysis on the conservation policies, ecological and other sociopolitical and economic structures on these countries has to be done to provide better response to the question as to why forests in these countries show favourable trend, given random influences and the observed latent determinants of forest area dynamics.

Conclusion

This study has simplified the complex process of forest area dynamics, as an outcome of a country's path in achieving higher levels of human development, obtaining higher earnings from forest product exports, rural population patterns and institutional and political conditions. We find that assumption of homogeneity among Asian countries provides significant U-shaped forests transition pattern. Within-country variation in forest area variation is attributed significantly to the level of human development and export of forest products.

[17] OLS estimates are derived using the RE model. Although a digression from the econometric models used in this paper, it contributes in showing the need for further exploration of political and institutional impacts on forest area variation in Asia.

Positive trade effects on forest area suggests potential role of market incentives in channeling public and private investments in expanding forest plantations and promoting sustainable forest management. However, we do not claim a causal link between these significant parameters. Forest policies establishing legal framework for long-term management of forests, forest incentives to set-up forest plantations, certified areas within national indicators and criteria of sustainable forest management schemes are much needed. Moreover, with forests identified as potential carbon sinks, national forest management schemes are subjected to future international forest negotiations.

Country-specific structures and time-specific disturbances on forests in Asia suggest unfavourable trend for most countries in the study. These random sources of variation such as ecological factors, land-use patterns, distribution patterns, property rights regimes, market structures, government policy interventions and among others, collectively operate to affect variation in forest area. Variance components, be it country-specific or period-specific, can be seen as possible reasons for empirical irregularity on the quantitative effect of latent factors of forest area dynamics in Asia. Further, simultaneity of influences of the observed and unobserved effects support previous works suggesting a chain of causations in environmental issues.

Cross-country regression models offer quantitative results but fail to explain the reason behind such results and how parameters interact with each other. Only partial effects of the parameters are captured. Regional and global regression models have yet to escape from the difficulties in using panel data, omission bias and loss of degrees of freedom. Future researches can consider building appropriate models that can accommodate the multi-dimensional nature of forests transition, and to clearly account for simultaneity of influences of the latent factors on forest area variation. Also, future harmonization of forest policies has to be responsive to both heterogeneity of countries and to the dynamic response of various forest types to latent factors.

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