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Comparative study of the forest transition pathways of nine Asia-Pacific countries☆

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ABSTRACT

Forest transition (FT) over the last three decades has attracted much academic attention. In this paper we present a comparative study of FT to assess regional variety in nine countries in Asia: China, Japan, the Republic of Korea, India, Indonesia, Malaysia, the Philippines, Laos and Vietnam, using data covering the years 1960–2010. This study's examination of changes in forest area demonstrates that Korea and Japan achieved FT before the 1980s, and that China, Vietnam, India and the Philippines achieved FT more recently, while Indonesia, Malaysia and Laos still experience forest cover decline. Economic development pathway and state forest policy pathway are most common in these nine countries. The globalization pathway is also found to contribute to FT, primarily in countries that are net importers of forest products. The land use intensification pathway is not identified in any of the nine countries. This study also observed that four countries (China, Vietnam, India and the Philippines) tend to achieve FT at relatively low income levels, which may point to the significance of state intervention in the region's countries via forest protection laws, national forest planning and afforestation programs.

1. Introduction

Forest transition (FT) is the change from decreasing to increasing forest area (Mather, 1992). The process is now recognized to be common to many countries in temperate and tropical regions (Geist and Lambin, 2002; Lambin and Meyfroidt, 2010; Rudel et al., 2005). Complex factors influence forest degradation and deforestation, and understanding these requires a historical geographic perspective; local, regional and global economic, political and environmental events and processes can have significant impacts on the change in forest cover at national levels (Mather et al., 1999; Barbier et al., 2010; Clement and Amezaga, 2008; Meyfroidt and Lambin, 2009; Klooster, 2003), and the same holds true for FT (Lambin et al., 2003; Mather, 1992).

Rudel et al. (2005) presented two economic models commonly used to predict future forest conditions, identified as: the economic development pathway and the forest scarcity pathway. In the first case, the process of economic development results in more intensive agricultural production and, concurrently, more economically attractive opportunities are created in cities and towns, which promotes rural-urban migration, leading to abandonment of agricultural land that reverts to forest. In the second case, rises in the price of forest products caused by scarcity of forests boost tree planting and thus contributed to forest recovery and rehabilitation. Based on Rudel's work, Meyfroidt and Lambin (2011) argue that FT also occurs along three additional pathways, all of which are dependent upon local socioeconomic and ecological conditions. Countries or regions may experience different pathways to FT given different development trajectories, and forest transition may follow several pathways at the same time in a specific country or region. The pathways include: 1) forest scarcity pathway, 2) economic development pathway, 3) state forest policy pathway, 4) globalization pathway, 5) smallholder, tree-based land use intensification pathway.

This paper takes Meyfroidt and Lambin's (2011) distinction of five FT pathways as a basis and pursues a comparative analysis of FT pathways in nine selected countries in the Asia-Pacific region, including China, Japan, the Republic of Korea, India, Indonesia, Malaysia, the Philippines, Laos and Vietnam. The paper assesses each country's pathway to FT while identifying and comparing basic drivers of forest cover change. The Asia-Pacific region is rich in forest resources, containing an estimated 600 million ha of forest, equal to approximately 17% of global forest area. Moreover, this region had the largest increase of forest cover in the period of 2001–2010, compared to other global regions (FAO, 2012). The majority of Asia's forests are located in China followed by Indonesia, India, Japan, Malaysia, and Laos.

Forest cover dynamics vary greatly in the Asia-Pacific region. China, India, and Vietnam have the highest rates of plantation establishment in the world and such rapid increases in forest cover have contributed significantly to reducing the global decline in forest cover (FAO, 2012). FTs in China and Vietnam are considered to be following the forest scarcity pathway (Mather, 2007) or the economic development pathway

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Table 1
Sources and time span of variables.

Variables	Abbr.	Unit	Time span	Source
Dependent Variables				
Deforestation	DF	1000 km^2		World Bank (2014); Liu (2014)
China	CHN		1962–2011	
Japan	JPN		1966–2011	
Republic of Korea	KOR		1960–2011	
Vietnam	VNM		1960–2011	
Laos	LAO		1968–2011	
Philippines	PHL		1961–2011	
Indonesia	IDN		1968–2011	
India	IND		1961–2011	
Malaysia	MYS		1966–2011	
Independent Variables				
GDP per capita	GDPPC	1000 constant 2005 US$	1960–2011	World Bank (2014)
Rural population density	RP	Capita per km^2	1960–2010	World Bank (2014)
Population growth	PG	% of population	1961–2010	World Bank (2014)
Agricultural land	AL	1000 km^2	1960–2010	World Bank (2014)
Cereal yield per hectare	CY	Ton per ha	1960–2010	World Bank (2014)
Forest protect laws	FL	1 if yes and 0 if no	1960–2012	Liu (2014)
National forest plan or decree	FP	1 if yes and 0 if no	1960–2012	Liu (2014)
Forest products and roundwood export Value	EV	Mil. US$	1961–2012	FAO
Forest products and roundwood import Value	IV	Mil. US$	1961–2012	FAO

(Zhang et al., 2006). The Republic of Korea, on the other hand, is claimed to follow a state forest policy and globalization forest transition pathway (Lambin and Meyfroidt, 2010). These arguments are supported by de Jong (2010), who holds that reforestation efforts have been a major policy priority in these countries since the 1980s. Both China and the Republic of Korea have adopted and implemented settlement programs, land classification schemes, decentralized forest management and reforestation programs (Clement and Amezaga, 2008). De Jong (2010) asserts that economic growth, national forest policies, and forest management systems have led to increases in forested area in China since the 1980s and Vietnam since the 1990s. The historical efforts of China and Vietnam to fight illegal logging, to increase investment in large-scale plantations, and to establish vast areas of national nature reserves are regarded as important drivers in the increase of forest area in both countries (De Jong, 2010). In Indonesia and Malaysia, forest resources have continuously declined and deforestation and forest degradation in Laos has become increasingly serious (FAO, 2012), although the latest Global Forest Resources Assessments (FRA) (FAO, 2015) indicates an increase in forest cover in Laos in recent years. The FT literatures, we argue lacks regional comparative approaches and that makes use of new sets of data that have become available in recent years. In this paper we aim to contribute to filling this gap, by comparing FT in the nine countries in the Asia-Pacific region listed above, in order to assess each country's pathway to FT while identifying and comparing basic drivers of forest cover change. We will furthermore explore how the FTs in the countries, compare to the five explanatory pathways proposed by various theoreticians on FT.

2. Data and model specification

2.1. Data sources

We used two main sources to develop a dataset related to the socio-economic and forest factors across nine countries in the Asia-Pacific region from the 1960s to 2011. Firstly, some data was collected as part of the APFFRI project entitled "Comparative Analyses of Transitions to Sustainable Forest Management and Rehabilitation" (APAFRI, 2013). This project has yielded nine reports, each of which provides an analysis of forest transition in one of nine countries: China, India, Indonesia, Japan, the Republic of Korea, Laos, Malaysia, the Philippines and Vietnam. These nine countries were selected for their diverse array of forest resources and because it was anticipated that their pathways to FT would vary. Secondly, data available from various public sources (i.e. FAO, 2012 and World Bank, 2014) was used. Table 1 provides a detailed description of the data sources of the dependent and independent variables used to assess the importance of drivers of forest transition. The following section describes each variable that we used to correlate forest trends to other factors.

In this study, we consider the following variables: deforestation, GDP per capita, rural population density, population growth, agricultural land, cereal yield per hectare, forest protection laws, national forest plan or decree, forest products and roundwood export value, and forest products and roundwood import value.

The sources and time span of variables are shown in Table 1.

2.2. Variables

2.2.1. Deforestation

The dependent variable used to compare FT in the nine countries considered in this study is deforestation (DF) area per year. We calculated DF by trends in forest area (FA). As the first step, we obtained FA data from the 1960s to the 2010s, the former being the earliest period for which reliable nationwide data was available. The FAO database has appropriate data only for the years after 1990, hence data for the period prior to the 1990s was taken from country reports. As the second step, we adjusted FA[1] data into one uniform statistical standard. Data for the years before 1990 came from the countries being studied and these countries used different statistical standards for forest or, within a country, standards were not consistent throughout the time period studied.[2] To compensate for such difference, FA has been adjusted as follows:

$$\text{Average adjusted ratio (ADr)} = [\sum \text{FA (country report, i year between 1990–2010)}/\text{FA (FAO, i year between 1990–2010)}]/n * 100\% \quad (2-1)$$

[1] Forest area (FA) has been defined by FAO as land under natural or planted stands of trees of at least 5 m high, and with each stand having a minimum crown area cover of 0.5 ha, but excluding tree stands in agricultural fields or trees in urban parks and gardens.

[2] For instance, in 1993, there were some modifications of the criteria to calculate forest area in China. Two modifications were the criterion for forest canopy density changed from >0.3 to >0.2 and the criterion for successfully afforested land changed from a ratio of 85% to 80% of surviving trees per hectare/number of planted trees per hectare.

Then we obtain FA for each year before 1990 using the same criteria defined by FAO:

$$\text{FA (adjusted, i year before 1990} = \text{FA (country report, i year before 1990)} * \text{ADr}. \quad (2-2)$$

As the third step, we adjusted gaps in the FA data into continuous yearly data. FA is generally collected every several years (e.g. every five years in China) and to fill in the gaps, linear interpolation based on the simplest forest growth model was used. If we assume that forest data is collected every t year, then data for FA is only available in the first year (FA_n) and the t year (FA_{n+t}). To get FA_k (forest area in any year between n and $n+t$) the following equation can be used:

$$FA_k = FA_n + (FA_{n+t} - FA_n) * \frac{k-n}{t}, n \le k \le n+t. \quad (2-3)$$

Finally, to get adjusted annual DF data:

$$DF_{t-1}(\text{adjusted, annual}) = FA_{t-1}(\text{adjusted, annual}) - FA_t(\text{adjusted, annual}). \quad (2-4)$$

If the value of DF increases, it means continuously aggravated net loss in FA; if the value decreases or even becomes negative, it means net growth in FA.

2.2.2. Economic development

Economic growth is regarded as one of the most significant drivers of forest cover change (Bhattarai and Hammig, 2001; Barbier, 2001; Koop and Tole, 1999). The forest environmental Kuznets curve (fEKC) is a widely used analytic framework to evaluate the relationship between economic growth and deforestation (Barbier, 2004; Cropper and Griffiths, 1994; Culas, 2012). If we consider deforestation as a component of environmental deterioration, and if the trend of deforestation follows the inverted U-shaped relationship as described by a fEKC, analogous to trends of air and water quality (Grossman and Krueger, 1995), economic development (measured as GDP or GDP per capita, GDPPC) will eventually begin to correlate with an increase in forest area. The economic development pathway theory further explains how economic development and, thus, growth in GDPPC leads to FT (Rudel et al., 2005). Therefore, GDPPC is specified as the indicator variable for economic development in the model. Existing evidence on the efficacy of FEKC is mixed (Koop and Tole, 1999; Zhang et al., 2006; Bhattarai and Hammig, 2001; Ehrhardt-Martinez et al., 2002), but in any case cross-country regressions with panel data cannot necessarily be used to infer that increases in GDPPC will eventually lead to an increase in forest area, and it is exactly for this reason that this paper uses ordinary least square (OLS) analysis for each country, instead of regressions with panel data.

2.2.3. Population dynamics

Many studies have singled out population growth as one of the most important causes of deforestation (Vanclay, 1993; Houghton, 1991; Myer and Turner, 1992; Wibowo and Byron, 1999). Geist and Lambin's (2001) meta-analysis of 152 case studies throughout the tropics indicated that three-quarters of surveyed literature included population as a proximate or underlying cause of deforestation. Population growth and rural population density are two population-related variables that have been widely used in previous empirical studies on deforestation, and excessive population growth and population pressure in developing economies are commonly cited as key factors inducing excessive tropical deforestation (Myers, 1994; Cropper and Griffiths, 1994; Carr, 2009; Allen and Barnes, 1985). Templeton and Scherr (1999), however, claim that population pressure is a double-edged sword: population pressure may initially increase deforestation, but once the population reaches a certain level, agricultural production become more efficient, thereby reducing the amount of forest land required for agricultural production.

Considering the complex role of population dynamics on deforestation processes we use both population growth and rural population density in the model. This approach allows us to assess the significance of both rural population pressure and overall national population levels on forest dynamics.

2.2.4. Agricultural land expansion

Agricultural expansion is considered a significant contributor to deforestation (Barbier, 2001; Cropper et al., 1999; Panayotou and Sungsuwan, 1994; DeFries and Pandey, 2010). Recently, the causal factors that result in the conversion of forests to farmland have attracted considerable attention in the literature on forest land changes in less developed economies (Morton et al., 2006; Meyfroidt and Lambin, 2008). We use agricultural land area as an independent variable to control for the effects of forest conversion to farmland. Koh and Wilcove (2008) use national land-use data compiled by FAO to determine the types of land that have been converted to oil palm in Malaysia and Indonesia. They present a framework for assessing the impact of oil palm agriculture on biodiversity; for instance, how oil palm plantations in Malaysia and Indonesia have been created from both existing agricultural lands and forests.

2.2.5. Agricultural intensification

To test the role of the intensification pathway on forest cover change, we use cereal yield per hectare as an indicator variable for agricultural intensification. Using the assumption that agricultural technology coincides with economic growth, cereal yield per unit area is used as a variable to measure the progress of agricultural technology. Cereal yield is also closely related to forest conversion to farmland and population change. Due to market development, agricultural intensification is typically concentrated in the most agriculturally suitable regions. As farmers adopt more productive agricultural technologies, crop production increases in these core agricultural regions and becomes unprofitable in marginal areas thereby contributing to reforestation (Mather and Needle, 1998).

2.2.6. Forest protection laws and the national forest plans

In some countries, the reasons for FT are closely related to the impact of forest governance (e.g. regulations, policies and management systems), and forest trends have been positively correlated with quality of governance (Deacon, 1994; Southgate et al., 1991; Weiland, 2010; Didia, 1997). Depending on the mode of implementation and overall effectiveness, this can lead countries to follow the “forest scarcity pathway” or “state forest policy pathway”. We use forest protection laws and national forest plans or decrees as two binary variables in the model. If a country enacted forest protection laws, plans or decrees, the value of the forest protection variable was set to 1, otherwise the value was set to 0 (see Table A in Appendix).

2.2.7. Global trade of forest products and timber

With the advance of globalization and the expansion of international trade, global trade in forest products and timber has played an increasingly significant role in forest area changes (Meyfroidt and Lambin, 2009; Kauppi et al., 2006). The spectacular increasing domestic demand for timber and forest products called for rapidly increasing demand from global market, to compensate for shorts in domestic production at a time. For instance, China's imports of industrial roundwood increased by 98% from 1998 to 2000 and by 199% between 1998 and 2004 (Mather, 2007). These increases have been linked to increased deforestation and forest degradation in some Southeast Asian countries (Lang and Chan, 2006; Zhu et al., 2004; Rudel, 2002). We use the export and import values for forest products and roundwood from the FAO database to evaluate direct sales as well as leakage from forestland elsewhere.

Table 2
Descriptive statistics for Variables.

Variables	Abbr.	Obs.	Mean	Std. dev.	Min	Max
Deforestation	DF	416	−1.6955	9.0107	−45.75	20.79
GDP per capita	GDPPC	429	4.9731	8.9399	0.0855	37.18
Rural population density	RP	429	104.46	285.09	0.0073	1382.74
Population growth	PG	459	347.11	193.81	99.81	898.27
Agricultural land	AL	477	1.8069	0.7914	−1.0155	3.3453
Cereal yield per hectare	CY	459	792.43	1459.9	14.50	5272.50
Forest protection laws	FL	468	3.2717	1.6072	0.8125	7.2650
National forest plan or decree	FP	477	0.4088	0.4921	0	1
Forest products and roundwood export value	EV	477	0.3144	0.4647	0	1
Forest products and roundwood import value	IV	444	1314.47	2033.86	0.01401	13,699.35

2.3. Model specification

Studies of this kind commonly use panel data (Koop and Tole, 1999; Foster and Rosenzweig, 2003; Rudel, 2002) and the econometric techniques used are variants of regression methods. However, when panel data is used every country has a fEKC of the same shape (same turning points and same curvatures), the only difference being that the levels of these curves vary for country to country (i.e. different intercepts), as the curves inflect at the same value of deforestation/forest cover. The choice of model occurs against the reality of forest recovery, if it exists, that takes place at different income levels in different countries. For this reason, this paper establishes nine time series datasets, one for each country, and adopts the ordinary least squares (OLS) method, instead of time series model, to estimate the parameters, considering our model doesn't include any lagged variable (Wooldridge, 2005). To make sure the stationary processes of both dependent and independent variables, first-order difference or second-order difference have been used to process the data (Hamilton, 1994), and then we can use OLS to estimate the post-processed variables.

We set the simplest equation form as:

$$Y_i = \beta_1 + \beta_2 X_i + \mu_i. \qquad (2-4)$$

Then obtain the deviations of X_i and Y_i as:

$$x_i = (X_i - X), y_i = (Y_i - Y). \qquad (2-5)$$

We minimize:

$$\sum \hat{u}_i^2 = \sum \left(Y_i - \hat{\beta}_1 - \hat{\beta}_2 X_i\right)^2 \qquad (2-6)$$

$$\frac{\partial\left(\sum \hat{u}_i^2\right)}{\partial \hat{\beta}_1} = \frac{\partial \sum \left(Y_i - \hat{\beta}_1 - \hat{\beta}_2 X_i\right)^2}{\partial \hat{\beta}_1} = -2\sum\left(Y_i - \hat{\beta}_1 - \hat{\beta}_2 X_i\right) \qquad (2-7)$$

$$\frac{\partial\left(\sum \hat{u}_i^2\right)}{\partial \hat{\beta}_2} = \frac{\partial \sum \left(Y_i - \hat{\beta}_1 - \hat{\beta}_2 X_i\right)^2}{\partial \hat{\beta}_2} = -2\sum\left(Y_i - \hat{\beta}_1 - \hat{\beta}_2 X_i\right)X_i. \qquad (2-8)$$

To obtain the first-order condition:

$$\begin{aligned} -2\sum\left(Y_i - \hat{\beta}_1 - \hat{\beta}_2 X_i\right) &= 0 \\ -2\sum\left(Y_i - \hat{\beta}_1 - \hat{\beta}_2 X_i\right)X_i &= 0. \end{aligned} \qquad (2-9)$$

And then get the normal equation:

$$\begin{aligned} \sum Y_i &= n\hat{\beta}_1 + \hat{\beta}_2 \sum X_i \\ \sum Y_i X_i &= \hat{\beta}_1 \sum X_i + \hat{\beta}_2 \sum X_i^2. \end{aligned} \qquad (2-10)$$

To obtain the parameters $\hat{\beta}_1$ and $\hat{\beta}_2$:

$$\hat{\beta}_2 = \frac{\sum (X_i - \overline{X})(Y_i - \overline{Y})}{\sum (X_i - \overline{X})^2} = \frac{\sum x_i y_i}{\sum x_i^2} \qquad (2-11)$$

$$\hat{\beta}_1 = \overline{Y} - \hat{\beta}_2 \overline{X}. \qquad (2-12)$$

Finally we obtain the fitting result:

$$\overline{Y} = \hat{\beta}_1 + \hat{\beta}_2 \overline{X}. \qquad (2-13)$$

We adopt a linear regression model based on the variables specified in Table 1. The coefficients of the variables are represented by βs and the error term by ε. Thus, the simple model is set as follows:

$$DF = \beta_0 + \beta_1 GDPPC + \beta_2 GDPPC^2 + \varepsilon. \qquad (2-14)$$

The simple model (2–14) only relies on GDPPC and $GDPPC^2$ as independent variables designed to examine whether there is a fEKC relationship between economic development and change in DF. The extensive model (2–15) not only includes GDPPC and $GDPPC^2$, but also contains independent variables which measure the influences of population growth, forest protect laws, land conversation and globalization, resulting in the following:

$$\begin{aligned} DF = {} & \beta_0 + \beta_1 GDPPC + \beta_2 GDPPC^2 + \beta_3 RP + \beta_4 PG + \beta_5 AL \\ & + \beta_6 CY + \beta_7 7TA + \beta_8 FL + \beta_9 FP + \beta_{10} EV + \beta_{11} IV + \varepsilon. \end{aligned} \qquad (2-15)$$

Descriptive statistics for variables are provided in Table 2.

Table 3
Regression results of simple model.

Variables	CHN	JPN	KOR	VNM	LAO	PHL	IDN	IND	MYS
GDPPC	−316.73***	−0.0047	0.0052	−236.98**	8.3789	−2.0678	−270.36	79.29	−7.8564
$GDPPC^2$	44.71***	−2.85e−07	−2.41e−07	0.1068***	−0.0015	−0.0030	0.1251	−0.0201	0.6690
Constant term	−4.11*	34.22	71.96	1475.64***	586.35***	−46.61	3774.05	−4418.43***	1.168623
R-squared	0.5103	0.1015	0.0071	0.6270	0.2825	0.1870	0.0378	0.3689	0.0039
Number of obs	49	45	51	27	27	31	31	51	45

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

Table 4
Regression results of extensive model.

Variables	CHN	JPN	KOR	VNM	LAO	PHL	IDN	IND	MYS
GDPPC	−193.06***	0.0955	0.0314*	−74.09**	−9.0138	−36.03	893.47**	−67.45	−20.55
GDPPC^2	19.78*	−0.0011	−0.0011*	107.16***	18.63*	18.39	−358.35**	109.85***	2.3475
RP	0.7149	0.0085**	0.0005	0.0309	0.0095***	0.1610	−2.1907	0.1126	1.1649
PG	−6.8630*	0.0016	−0.0174***	3.8392***	−0.0039	2.0509**	−54.83**	6.9181**	−4.9325
AL	0.0064	0.0307	0.0282	0.3054	0.0265	0.8171	−1.3821	0.0888***	3.0768
CY	−6.3384	−0.0302	−0.0036	1.7731	−0.0031	−4.2612	−49.08*	−0.9642	23.95
FL	−17.82*		−0.0078	−0.8085	0.0746	−0.2148	−6.1285	−3.8861***	
FP	−6.2949		−0.0269**			0.1105		0.3516	
EV	0.0016	0.0002	0.0001	0.00528*	−0.0001	0.0027*	0.0024	−0.0048	−0.0057
IV	0.0001	−1.94e−07	−3.17e−06	0.00105**	−0.0058	−0.0019	0.0043	−0.0024***	−0.0039
Constant term	−11.95	0.2812	0.1214***	−8.4353***	−1.4402***	−6.0601**	101.02*	−180.67***	12.05
R-squared	0.6662	0.2563	0.3058	0.9439	0.8329	0.6809	0.7662	0.8335	0.2939
Number of obs	49	45	49	25	27	42	32	49	45

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

3. Results and analysis

3.1. Regression results

Tables 3 and 4 present the results from the econometric regression. Table 3 is the regression result of the simple model (2–14) and Table 4 is the result of the extensive model (2–15).[3]

The relationships between DF and the GDPPC for the nine countries (Table 3) reveal the dynamic interaction of forest area change and economic growth. The so-called fEKC inverted U-shaped curve is not significant in any country when we only take GDPPC into consideration.[4] Detailed analysis will be in part of Section 3.2.

When more factors are taken into consideration, the results change a bit. The addition of more variables results in GDPPC and GDPPC^2 being significant in Laos, Indonesia, India and Malaysia, as well as in China and Vietnam. But when we consider that forest area in Indonesia, Laos and Malaysia is still declining, we can conclude that these three countries have not yet realized FT, but find themselves still in the first stage of FT — that of forest area decreasing while GDPPC is growing.

3.2. Analysis

This part analyses the economic results above combined with statistic graphs and tables in detail.

3.2.1. Economic development

In addition to the econometric analysis above, the whole period of our study has been divided into four phases for descriptive analyses, respectively 1960s–1980, 1980–1990, 1990–2000 and 2000–2010. Figs. 1 and 2 show the changes in FA and GDPPC for the entire period of the study for the 1960s to 2010, in which negative annual change in FA means the net loss in FA in one of these periods.

The econometric results in Table 3 show that the so-called fEKC is not significant in any country when we only take GDPPC into consideration. Figs. 1 and 2 also verify this econometric conclusion that no significant fEKC relationships exist among countries with different GDPPC levels.

Seeing Figs. 1 and 2, during the whole period from the 1960s to the 2010s, change in the FA of Japan was nearly stagnant, while the annual growth of GDPPC was about 4% annually in the period of 1960s to 1980s and 0.7% in the 1990s to 2010s, which indicates that GDPPC growth did not significantly affect FA. The same is true for Korea. One probable reason is that both Japan and Korea had achieved FT before their economic take-offs (which occurred roughly during the 1960s–1980s) and, hence, their forest areas remained steady or changed only slightly after the 1970s. Fig. 2 reveals that China, Vietnam, the Philippines, and India achieved FT in the last several decades, while Laos, Indonesia and Malaysia continue to experience forest loss (i.e. change in GDPPC is positive while FA is negative in phases 3 and 4). In general, Korea and Japan achieved FT before the 1980s, China, Vietnam, India and the Philippines[5] achieved FT in recent decades, while Indonesia, Malaysia and Laos still experience forest cover decline.

Our study also verifies that GDPPC is not the only decisive factor of forest cover change. Countries experienced forest recovery at different levels of GDPPC, with recovery occurring at $200 GDPPC in China in the 1980s while Malaysia continues to experience forest loss despite a GDPPC of $6000 in 2012. Moreover, several of the FT countries in this study, namely China, India, Vietnam and the Philippines, began their forest recovery at relatively low levels of GDPPC. We have already noted that China began to reverse deforestation trends when GDPPC was just $200, while India, Vietnam and the Philippines achieved FT at approximately GDPPCs of $350, $300 and $1000 respectively. The forest area of Laos, on the other hand, continued to decline when its GDPPC exceeded $700 in 2012. We conclude there is no uniform economic threshold that signals when FT will occur for developing countries today.

3.2.2. Population dynamics

The coefficient of rural population density is positively correlated with DF in Japan and Laos, which means that rural population density increases aggravate deforestation while declines in rural population density lessen deforestation. In terms of total population growth, the coefficient of that in China, Indonesia and Korea are negative. Generally, forest areas in Indonesia and Korea have decreased in last four decades, hence the negative coefficient of the rural population density means population growth caused deforestation in these two countries.

On the other hand, a decrease in DF occurred in China in past decades concurrently with an increase in the total population, which means population pressure did not result in the growth of deforestation. In Vietnam, the Philippines and India, the coefficient of population growth against deforestation is positive but decreasing, which means total population growth has accelerated while deforestation has decreased.

[3] If an independent variable has a positive value, this means that variable is a factor aggravating deforestation or, in other words, contributing to a decline of forest area.

[4] If there is a fEKC inverted U-shaped curve, the coefficient of GDPPC^2 should be negative while GDPPC positive; hence, despite the significant coefficients in China and Vietnam, the shapes of the curves are the reverse of fEKCs.

[5] Mather (2007) suggested the annual change in forest area is −2.1% in the Philippines. But according to the data of FAO and Philippines country reports, forest area has increased continuously since the 1990s and, therefore, we do think the Philippines has achieved FT.

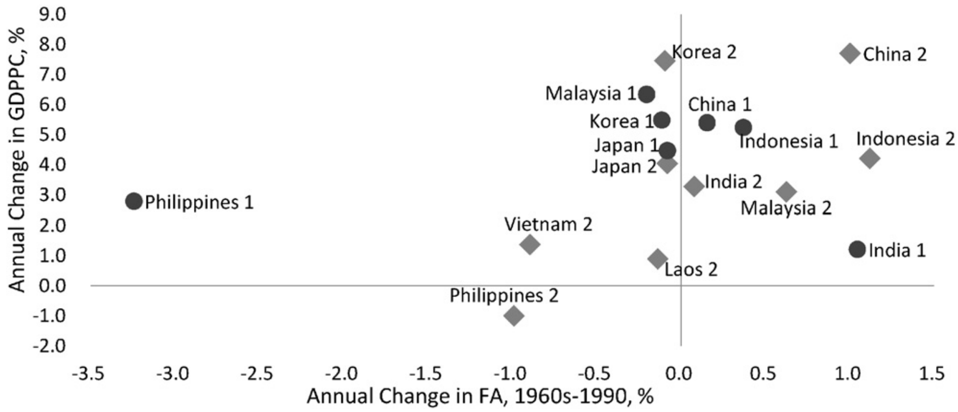

Fig. 1. Changes in FA and GDP per capita, 1960s–1990. Note: ● and "country name 1" refer to phase 1 (1960s–1980); and "country name 2" refer to phase 2 (1980–1990). The actual years covered by phase 1 varies from country to country: China, 1962–1980; Japan, 1966–1980; Korea, 1960–1980; India, 1961–1980; Indonesia, 1968–1980; Malaysia, 1963–1980; the Philippines, 1969–1980.

3.2.3. Land conversion

The results of our econometric analysis reveal that agricultural land expansion does not necessarily lead to deforestation, this coefficient is significant only in India.

Fig. 3 shows total changes in arable land and agricultural land with concurrent total change in forest area. China and India show increases in agricultural land, arable land and forest area during the period of the study (dots for these countries are in the first quadrant), which indicates that forest area and agricultural land have increased simultaneously and that the increase in agricultural land has not put pressure on forest area. Only Japan and Korea have shown decreases in all three kinds of land (dots in the third quadrant). The Philippines, Indonesia, Vietnam, Laos and Malaysia all show a net loss in forest area and net gains in both arable and agricultural land during the past four decades. In particular, the expansion of arable land and agricultural land has been significant in Laos and Malaysia.

3.2.4. Forest governance

The results show that forest protection laws and the national forest plans were positively related to increases of forest area in China, India and Republic of Korea, which means forest protection laws and national forest plans significantly contribute to forest recovery. Combined with analysis of GDP, the achievement of FT at a low GDPPC is particularly likely to be the case in countries where state policies and governance have played an important role in offsetting forest loss.

For instance in China, beginning in 1998, the state has implemented a number of major programs that have led to large public investments in afforestation and infrastructure development with funds earmarked for forest resources protection, timber supply development, reforestation, soil and water conservation, and biodiversity preservation. Including the Natural Forest Protection Project (NFPP), the Grain for Green Program, the Key Shelterbelt Development Program along the Yangtze River, the Coastal Shelterbelt Program, the Key Shelterbelt Development Program in the three northern regions, and Desertification Control Program in Greater Beijing and Tianjin. Funding for these six projects adds up to an investment of more than US$ 113 billion (SFA, 2009). For example, the "Three Northern Shelterbelts" project launched in 1978 was China's first ambitious ecological restoration effort. This project, envisaged to last until 2050, includes a land area of 400 million ha, accounting for 42.4% of China's land mass (Ma, 2004).

3.2.5. Globalization

Tables 5 and 6 show the annual changes in forest area, and the export (EV) and import values (IV) of forest products and roundwood. The coefficient EV is significantly positive in Vietnam and the Philippines while IV is significantly negative in India, which suggests that imports have a positive effect on forest area (i.e., a negative effect on deforestation) while exports have a negative effect on forest recovery. Tables 5 and 6 show the details of annual changes in FA, EV and IV from 1960 to 2010 in all of the nine countries studied.

In countries that have achieved FT, namely Japan, Korea, China, India, the Philippines and Vietnam, growth in the value of imports of forest products and roundwood has generally been much greater than growth of in the value of exports. This is especially true of the period just before FT when forest area begins to increase (Japan, Korea — 1960s, China —

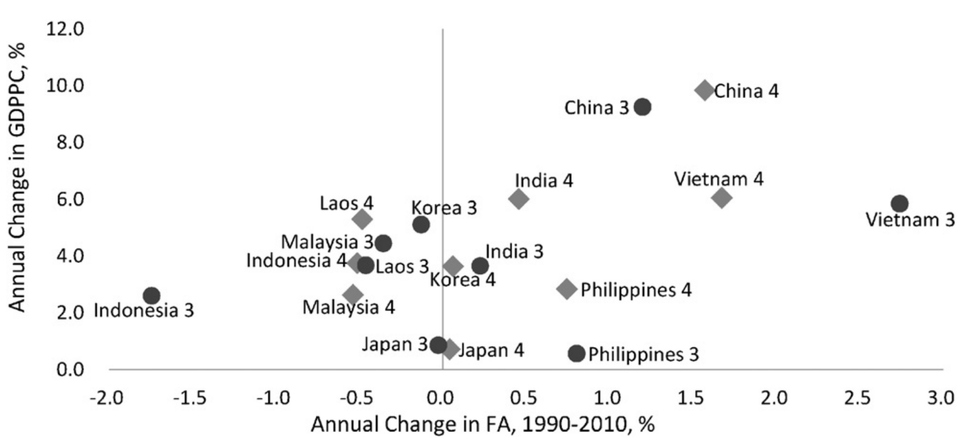

Fig. 2. Changes in FA and GDP per capita, 1990–2010. Note: ● and "country name 3" refer to phase 3 (1990–2000); and "country name 4" refer to phase 4 (2000 — 2010). Source: FAO, World Bank, National Reports.

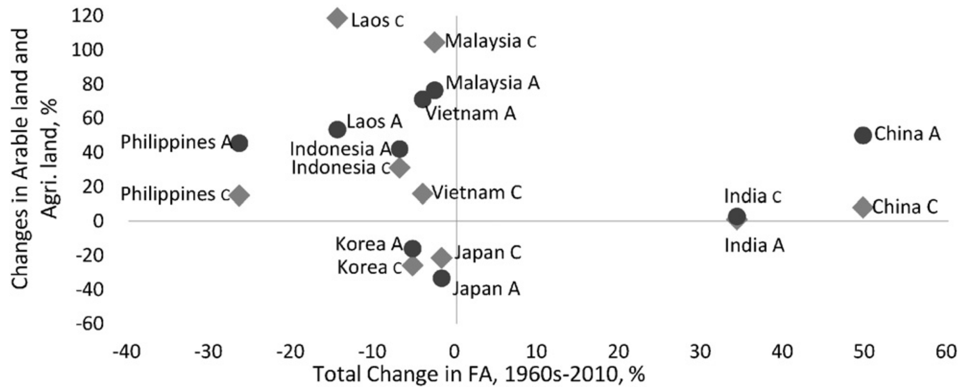

Fig. 3. The changes in forest, arable and agricultural land, 1960s–2010. Note: ● and "country name A" refer to Agricultural land; and "country name C" refer to arable land (cultivated land). Source: FAO, World Bank, National Reports.

1980s, Vietnam — 1990s). In countries which continue to endure forest loss (i.e. Laos, Indonesia and Malaysia), the percentage growth of export value has been slower than the percentage growth of import value, but, because the value of exports far exceeds that of imports (except for Malaysia, which is US$ 1.91 and 81.31 million for EV and IV respectively), the change in the amount of exports has surpassed the change in the amount of imports. This may be indicative of a leakage effect from the forest products industry in the Asia-Pacific region.

This paper also finds the globalization pathway important for FTs because some countries, particularly China and Vietnam, have been able to limit deforestation by importing forest products. On the other hand, expanding international trade via globalization tends to aggravate deforestation in most tropical countries because these countries often have rich forest resource endowments available for exploitation. However, some countries, which have become net importers, have avoided forest loss during industrialization and become the largest beneficiaries of globalization. For instance, an analysis of 176 countries suggests that rich countries meet their demands for forest products by appropriating resources from countries with lower GDPPC, while they actively promote forest conservation at home (Mills Busa, 2013). Another study on seven developing countries that recently achieved FT suggests that pressuring the removal of forest extraction industries to other countries was accompanied by local reforestation (Meyfroidt et al., 2010). About 39% of the regrowth of Vietnam's forests from 1987 to 2006 was achieved by displacing certain kinds of activities to other countries in ways that changed land use patterns (Meyfroidt and Lambin, 2009). China and India import large quantities of timber and forest products, successfully meeting domestic demand for these items while protecting domestic forest cover at the same time. Indonesia, Laos and Malaysia remain net exporters and continue to be negatively affected by globalization and international trade as far as FT is concerned. Globalization and expanding international trade continuously aggravate deforestation in export-oriented nations and delay the arrival of forest transition in these countries.

4. Conclusion

Observations of forest change in European countries originally led to the development of FT theory (Mather, 1992). Recently, a number of studies have reported on examples of Latin American FTs that are apparently different from the earlier European cases (Rudel, 2002; Baptista and Rudel, 2006; Barbier and Burgess, 1996; Hecht et al., 2006), implying different causal factors. Our study also suggests that FTs and FT pathways in the Asia-Pacific region are not identical to those studied in Europe and Latin America. In general, Korea and Japan achieved FT before the 1980s, China, Vietnam India and the Philippines achieved FT in recent decades, while Laos, Indonesia and Malaysia are still experiencing forest cover decline. This study also finds that among the five FT pathways examined, the economic development and state forest policy pathways are most common in the nine countries covered in the paper.

Previous econometric studies on forest dynamics (Bhattarai and Hammig, 2001; Cropper and Griffiths, 1994; Culas, 2012) that have used national-level panel data to describe region-wide characteristics have failed to adequately understand the complexity observed at the national level. This paper finds that several neighboring Asian economies are not homogeneous; each displays unique socio-economic conditions that shape their FTs. These differences likely grow out of each country's complex socio-political, economic, cultural and ecological history. As such, aggregating data for large geographical regions such as Asia and using it to inform policy and management decisions in the region should be avoided.

Table 5
Annual changes in FA, EV and IV, 1960s–1990.

Country	Years	Export value annual growth, %	Export value annual growth, mil. US$	Import value annual growth, %	Import value annual growth, mil. US$	FA annual change, %
China	1962–1990	14.76	54.63	16.27	217.00	0.46
Japan	1966–1990	9.69	58.42	11.33	679.42	−0.08
Korea	1961–1990	22.70	15.78	18.95	130.07	−0.11
India	1961–1990	3.74	1.01	11.16	27.12	0.71
Indonesia	1968–1990	23.22	141.61	15.64	20.53	0.71
Laos	1961–1990	23.89	0.82	3.95	0.02	−0.22
Malaysia	1963–1990	10.93	161.64	13.85	17.81	0.10
Philippines	1969–1990	−6.80	−19.25	11.09	11.00	−2.18
Vietnam	1985–1990	94.30	32.66	4.66	0.27	−1.51

Table 6
Annual changes in FA, EV and IV, 1990–2010.
Source: FAO (2012, 2015), World Bank (2014), Liu (2014).

Country	Years	Export value annual growth, %	Export value annual change, mil. US$	Import value annual growth, %	Import value annual change, mil. US$	FA annual change, %
China	1990–2010	9.90	438.46	9.47	1573.44	1.38
Japan	1990–2010	4.00	93.76	−1.57	−238.86	0.01
Korea	1990–2010	8.37	91.50	2.35	111.98	−0.03
India	1990–2010	13.75	27.29	10.16	244.21	0.34
Indonesia	1990–2010	4.30	207.64	8.62	99.46	−1.13
Laos	1990–2010	13.55	14.03	15.53	0.80	−0.47
Malaysia	1990–2010	0.04	1.91	7.54	81.31	−0.45
Philippines	1990–2010	4.07	7.28	4.24	16.81	0.77
Vietnam	1990–2010	8.01	31.11	34.18	118.40	2.21

The achievement of FT at a low GDPPC is particularly likely to be the case in countries where state policies and governance have played an important role in offsetting forest loss. Such as in China, India and Republic of Korea, forest protection laws and national forest plans significantly contribute to forest recovery.

This paper also finds the globalization pathway important for FTs because some countries, particularly China and Vietnam, have been able to limit deforestation by importing forest products; while in Indonesia, Laos and Malaysia, globalization and expanding international trade continuously aggravate deforestation in export-oriented nations and delay the arrival of forest transition in these countries.

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Appendix A

Table A
Forest protection laws and national forest plan or decree.

Name	Year	Main content
China		
Property Law	2007	Forest property rights are considered as property rights related to forests
Three Northern Shelterbelts System	1978	To treat soil erosion and sand storms in northern China
Forestry Law	1984	Forest resources are divided into state and collective forests. Collective forest land is owned and managed by rural collectives, and individuals are given rights to use and benefit from forests allocated to them
Forestry Law Amendment	1988	Timber forests, economic forests, fuel wood forests and their use rights are transferable, though conversion of forests to non-forest uses is prohibited
Environment Protection Law	1989	Means to control emissions to soil, air and water.
Natural Forest Protection Program	2000	Logging ban was implemented in Southwest, Northwest and Northeast China, in particular in the state forest region.
Forest Ecological Benefits Compensation System	2001	To extend the protection to forest resource
China Cooperation Organization Act	2007	Directly promoting the emergence of a large number of forestry cooperative organizations
Property Law	2007	Forest property rights are considered as the property rights related to forests
Forest Ecological Compensation Fund	2010	acts in the public interest and plays an important role in management of ecological forests with public funding and administration
India		
The Forest Policy	1952	Recommended bringing 33% of the total land area of the country under the forest cover, recognized the protective and productive functions of forests and underlined the importance of their protection
The National Commission on Agriculture and its Interim Report	1972	Emphasized production forestry (man-made forests) and recommended creation of Forest Development Corporations for enhancing the investment through bank financing and raising of large scale plantations through social forestry.
Wildlife (Protection) Act and Implementation	1972	Provides protection to wild animals, birds and plants and for matters connected therewith or ancillary or incidental thereto with a view to ensure ecological and environmental security of the country.
Forest Conservation Act	1980	In order to exercise control of the diversion of forests by state governments
National Forest Policy	1988	Lays prime emphasis on environmental stability and conservation of forests, while meeting domestic requirements for fuel wood, fodder, minor forest produce and construction timber for rural and tribal populations, and their participation in protection and management of forests
Joint Forest Management Circular	1990	Provided state governments with a framework for involvement of village communities in protection, regeneration and development of degraded forests situated in the vicinity of the villages
Forest Rights Act	2006	Provides for the restitution of deprived forest rights across India, including both individual rights to cultivated land in forest areas and community rights over common property resources
Indonesia		
Basic Forestry Law	1967	Uses regulations inherited from the Dutch Colonial Government to regulate forestry affairs
Presidential Decree on Protected Areas	1990	Uses regulations to regulate protected areas and living natural resources
Conservation Act	1990	Uses regulations to regulate protected areas and living natural resources
The Forestry Act	1999	Regulates and organizes all aspects related to forest, forest area, and forest products arranged in chapters
Japan		
Forest Basic Law	1964	To develop forestry in conjunction with timber demand during high economic growth periods
National Forest Plan		Provides national guidelines for forest management
Forest and Forestry Basic Plan	2006	Established based on the “Forest and Forestry Basic Law, and provides national guidelines for forest management; the fundamental national policy on forests and forestry in Japan; forests are categorized into three functional types according to their primary function
Forest and Forestry Basic Law	2001	A supplement to the “Forest Basic Law” enacted in 1964. To integrate multiple functions of forests.
Korea		
Erosion Control Act	1962	The act aimed to control soil and water erosion in the slope area.
Act on Distribution of Special Employees for Forest Protection	1963	To ensure payment to the employee for forest protection from public finance.
Act on National Forestry Cooperatives Federation	1980	Legal document to operate the forest cooperative federation.
Act on Promotion of Forestry and Mountain Villages	1997	Comprehensive rule to support social and economic development in the rural regions where rich in forests.
Framework Act on Forest	2001	Multi-functions of forests were strengthened, in particular forests for people's health and forest culture.
Act on Establishment and Promotion of Forest Arboretum	2001	Acts for administration of forest arboretum.
Forest Land Management Act	2002	Legal document in details for land management.
Act on Protection of Baekdu Daegan Mountains System	2003	

Table A (*continued*)

Name	Year	Main content
Act on Pine Wilt Disease Prevention	2005	
Act on Promotion and Management of Forest Resources	2005	Legal document to improve quality of forests.
Act on National Forest Management	2005	Legal document to manage the state forests.
Act on Forest Culture and Recreation	2005	
Act on Structural Improvement of National Forest Cooperatives Federation	2008	
Act on Forest Protection	2009	
Act on the Management and Improvement of Carbon Sink	2012	
National Forest Development Plans (first stage)	1973–1978	Focused on reforestation, total 41,932 ha erosion control works were conducted; 1.08 mil ha was successfully reforested
National Forest Development Plans (first stage)	1979-	Emphasized the establishment of large scale commercial forests for providing timber supply; 1.064 million ha was reforested
Comprehensive National Territorial Development Plans	1972–1981	Initiated building the foundation for long-term economic growth. It included resource development and environmental conservation
Laos		
Forestry Law 2007	2007	All types forest uses must make sure to avoid any negative impacts on forest resources and the natural environment, or society
Malaysia		
Sarawak's Forest Ordinance	1954	
Sabah's Forest Enactment	1968	
National Parks Act	1980	
National Forestry Act	1984	
Philippines		
Community-based Forest Management (CBFM)	1995	This rule provided legal document to support community forestry initiatives across Philippines.
National Greening program	2011	This rule aims to mobilize resources and provide incentives to green the country.
Vietnam		
Forest Protection and Development	1991	To involve local people and different economic sectors in forest protection and development
Prime Minister Decision 661/QD-TTg		The objectives, tasks, policies, and organizations for the establishment of 5 million ha of new forest

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