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Does Rapid Urbanization Drive Deforestation? Evidence From Southeast Asia

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Abstract

The issue of rapid deforestation is still ongoing in Southeast Asia. Urbanization boosts demand for land and processed food which can generate environmental degradation. This article intends to present the resuls of an investigation to the nexus between urbanization and deforestation in Southeast Asia from 1996 to 2020 as well as control economic and demographic factors. The data were collected from World Development Indicators and Our World in Data. The Pooled Mean Group (PMG) estimation and Dumitrescu-Hurlin (DH) were applied to examine the short- and long-run effect and the direction of causality variables. The co-integration test has confirmed that the long-run relationship was evident. The results supported the Ecological Modernization Theory (EMT) hypothesis that the relationship between urbanization and deforestation is non-linear, following an inverted U-shape. A turning point occured when the urbanization level reached 64.76%, i.e., the upper-acceleration stage. Rural-urban migration and urban population growth will continue to drive forest loss since Southeast Asia was dominated by low-level urbanization countries. Only Brunei and Malaysia surpassed the threshold of 64.76%. In addition, there is a bidirectional causality relationship between deforestation and urbanization. Strong integration between urban development policies and forest governance is required to reduce the damaging impact of urbanization on forest resources.

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INTRODUCTION

The year 2009 is noted as the beginning of Southeast Asia urbanization, where 50% of the population was first recorded to live in cities. United Nations, Department of Economic and Social Affairs (2018) projects that the urban population will increase to 64% by 2030 and 68% by 2050. An increase in the share of the urban population will occur because of the urbanization process that will still take place in developing countries marked by a significant difference between the growth rates of rural and urban inhabitants. The urban population increases at 2% per year, while the rural population only grows at 0.16% per year.

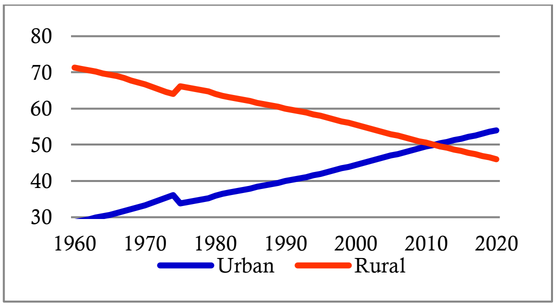

Figure 1. The number of people living in urban and rural area (%) in Southeast Asia,1960 – 2020. Source: WorldBank, 2022 (Processed)

Urbanization will shift the population from initially spreading in the villages to being concentrated in the cities. As a development process, urbanization is divided into three stages; initial, acceleration, and terminal, following the J-Curve (Mulligan, 2013). In the early phase, the national urbanization rate is still slow, and the population is distributed out in villages with a characteristic agricultural economic sector. The second phase refers to rapid urbanization where urban inhabitants increase significantly following the shifts economic sector. In the terminal stage, the urbanization rate slows down in line with the high-concentration urban inhabitant, economic structure being dominated by the manufacturing and service industries. Previous studies found that urbanization positively affects per capita income (Chen et al., 2014; Liddle & Messinis, 2015). In addition, agglomeration economies, ease of information distribution, and technology transfer are positive externalities of urbanization (Lyu et al., 2019).

Rapid urbanization has been confirmed in developing countries, including Southeast Asia in the last three decades. The urbanization rate for the period 2011 – 2020 was still relatively high (1.24%) but has begun to slow down when compared to the previous two decades, 1.62% (1990-1999) and 1.54% (2001-2010), respectively. Based on country specifics, rapid urbanization rates are still ongoing in Vietnam, Cambodia, Laos, Thailand, and Indonesia, respectively 2.07%, 1.79%, 1.90%, 1.61%, and 1.27% per year. In contrast, the rate of urbanization in the Philippines and Brunei Darussalam is relatively low, 0.43% and 0.45% per year, respectively. The accelerated urbanization stage still dominates Southeast Asia, representing high rural-urban migration and urban growth. There were only two countries with high urbanization levels, namely Malaysia (77.16%) and Brunei (78.25%), while other Southeast Asia countries were moderate and low.

Table 1. Urbanization Rate (%)

	1991-00	**2001-10**	**2011-20**
Upper middle income			
Brunei	0.69	0.52	0.43
Malaysia	2.21	1.36	0.85
Thailand	0.65	3.40	1.61
Lower middle income			
Indonesia	3.22	1.74	1.27
Kamboja	1.80	0.88	1.79
Laos	3.60	3.19	1.90
Filipina	-0.18	-0.18	0.45
Myanmar	0.68	0.67	0.75
Vietnam	1.87	2.24	2.07
	1,62	1,54	1,24

Source: Data processed, 2022

From a different dimension, urbanization is a crucial aspect of environmental degradation. Uncontrolled rapid urbanization and insufficient urban development policies negatively contribute to the environment. Several studies noted that urbanization causes carbon emission, ecological footprint, solid waste, nitrogen emission, and haze pollution (Y. Wang et al., 2016; Hussain & Rehman, 2021; He et al., 2021. F. Wang et al., 2021; Anh Tuan et al., 2021; Aung et al., 2017). Since the 21st century, urbanization is considered the root of changes in forest cover.

The drivers of forest degradation have shifted from village inhabitants and smallholders to industrial-scale agriculture and urbanization (Imai et al., 2018). Urbanization depresses forest resources through two main paths: (1) processed food consumption and (2) urban land expansion (Prugh, 2016). First, rural migrants adopt a city-based lifestyle, change their diet, and consume more processed food. This pattern encourages forest conversion into agricultural land to support food industries. In addition, urbanization has boosted the demand for forestry products, such as logs, paper, and pulp, thereby encouraging the extraction of more trees (Brack, 2018; Ancha et al., 2021).

Second, urbanization drives deforestation through urban land expansion (Prugh, 2016). The increase in urban population density due to rural-urban migration causes a boost in demand for land for infrastructure development, thus promoting forest conversion around the suburbs. Shrestha et al. (2012) note that rapid urbanization significantly drives fragmentation However, forest damage due to urban sprawl and leapfrog is lower than the one with consumptive behavior. Urbanization, along with GDP growth, industrialization, price, and trade, is the underlying cause of tropical deforestation from economic factors (Plata-Rocha et al., 2021; Geist & Lambin, 2002).

Urbanization and deforestation studies have been extensively written and employed panel or time-series data. Ehrhardt-Martinez et al. (2002) used cross-country data and the OLS estimation method to investigate deforestation from an economic and social perspective. The findings support EMT and EKC hypotheses. There is a non-linear relationship (inverted U-curve) between urbanization and deforestation. The turning point between urbanization and deforestation occurs when urbanization reaches 36%. In similar, the more recent empirical article proposed by Ajanaku & Collins (2021), Waluyo & Terawaki (2016), and Caravaggio (2020) also support the EKC hypothesis for income per capita and deforestation.

Defries et al. (2010) investigated the nexus between urbanization, agricultural trade, and deforestation by employing the liner and trees regression method and collecting data from a satellite. The results note that urban population growth and agricultural trade are the prominent drivers of deforestation. These empirical findings support an argument proposed by Prugh (2016). Urbanization is the root cause of deforestation due to changes in urban dwellers' lifestyles and urban size expansion. It is in line with Ajanaku & Collins (2021) that farming and forestry export are the drivers of deforestation in Sub Sahara Africa.

For single country analysis, Yameogo (2021) employed the ARDL bounds testing to examine the connection between urbanization, globalization, and deforestation in Burkina Faso. The study's findings have confirmed that urbanization is a short and long-term driver of deforestation. A 1% increase in urbanization resulted in a 0.39% increase in deforestation. Another finding is that income per capita only drives deforestation in the short run. The result in line with Nathaniel & Bekun (2020) that urbanization has a positive impact in both the short and long term for the Nigeria case study. Nevertheless, Izquierdo et al. (2011) propose that urbanization as a rural-urban migration process could benefit forest conservation if the drivers of deforestation are small farmers and villagers.

The connection between urbanization and deforestation may differ across regions. Referring to the existence of the issue of rapid urbanization in Southeast Asia, this paper presents the findings of an empirical which examined the impact of rapid urbanization on deforestation using panel data over the period 1996 – 2020 as well as control the economic and demographic factors as the underlying causes of forest cover change. The study of the non-linear link between urbanization and deforestation has been demonstrated by Ehrhardt-Martinez et al. (2002) using panel cross-countries. An empirical study of Southeast Asia is still neglected. The previous study only investigated the linear nexus between urbanization to deforestation (Imai et al., 2018).

For the study contribution, we proposed several novelties. First, this paper investigates the short- and long-run nexus between urbanization and deforestation. This study employed PMG for this case. Second, this study attempted to reveal the non-linear relationship between urbanization and deforestation. The previous literature only investigated linear regression using OLS (Imai et al., 2018). Finally, this study enhanced the panel causality test proposed by Dumitrescu & Hurlin (2012) to investigate the causal link and promote a better insight into the relationship between urbanization and deforestation.

RESEARCH METHODS

TThis study intended to investigate the non-linear relationship between urbanization and deforestation. It made use of panel data from nine Southeast Asian countries from 1996 to 2020. The length of the observation period was determined by the importance of the rapid urbanization issue and the availability of data. The variable deforestation rate was constructed using data on forest area (square km) obtained from the World Bank's statistical publication World Development Indicators (WDI). WDI also provided data on urbanization (percentage of the population living in cities), arable land area per capita (hectares per person), and GDP growth (2015 constant price). Data on Foreign Direct Investment (FDI) were sourced from WDI and Our World in Data (OWID). To avoid omitted variable bias, this study included control variables of macroeconomic and demographic factors in the empirical model. Additional control variables based on the study on underlying factor forest cover changes proposed by Geist & Lambin (2002) and Plata-Rocha et al., (2021).

Following the EKC and EMT hypothesis, as well as previous studies by Ehrhardt-Martinez et al. (2002), Yameogo (2021), Lokonon & Mounirou (2019) and Ajanaku & Collins (2021), Eq. 1 is the empirical model:

$$DEF_{it} = \beta_0 + \beta_1 URB_{it} + \beta_2 URB_{it}^2 + \beta_3 X' + \varepsilon_{it} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

DEF is deforestation. URB and UBR2 note level and quadratic form of urbanization. X is the control variable, i.e., economic growth (GDP), Foreign Direct Investment (FDI), arable land per capita (APC), and trade openness index (OPEN). β_0 is a constant. β_i is the coefficient. ε is an error term. Subscripts i and t represent country and year, respectively. It was expected that β_1 > 0 and β_2 < 0 so that a non-linear connection was evident, and the turning point can be calculated as follow:

$$T^* = [-\beta_1/(2 \times \beta_2)] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Deforestation is the dependent variable in this study. Deforestation can be defined in two ways: (1) narrowly; and (2) broadly. Deforestation in a narrow sense is the change in the area of forest cover (FAO, 2007). Deforestation is the process of removing forest cover and converting forest vegetation to non-forest vegetation (Hosonuma et al., 2012). The rate of the net change in forest cover area was used as a measure of deforestation in this study (Waluyo & Terawaki, 2016). The method of measuring deforestation is described in Eq 2.

$$DEF = [(F_{t-1} - F_t)/F_{t-1}] \times 100\% \quad \ldots\ldots\ldots\ldots (3)$$

DEF is the net deforestation rate. F is the area of forest cover. The subscript t is the analysis period. The subscript t-1 is the previous period. If the DEF value is positive, deforestation will occur, that is, the forest area in period t is smaller than the forest area in the previous period (t-1). On the other hand, if the DEF value is negative, reforestation and/or afforestation will occur, i.e., the forest area grows in comparison to the previous year (t-1).

Urbanization is the main independent and interest variable in this study. Urbanization is the root of forest cover change (Prugh, 2016). This study employed the share of the population living in the city as an indicator of urbanization. This metric depicts a country's degree of urbanization. In addition, this present study constructed quadratic form urbanization to check a non-linear relationship, following a study conducted by Ehrhardt-Martinez et al. (2002). Urbanization drives forest depletion through urban household consumption and city-size expansion. However, consumption preferences at the terminal level of urbanization may differ. In addition, strong environmental policies, innovations, and technologies may also be operational at this stage so that urban growth does not cause deforestation. This paper suggests that the relationship between urbanization and deforestation follows the inverted U-shape, i.e., supporting the EKC and EMT hypotheses.

To tackle omitted variable bias (OVB), this current study added macroeconomic and demographic as the control variable. Economic growth (Gross Domestic Product-GDP growth), foreign direct investment (% GDP net inflow), trade openness index (ratio sum of export and import to GDP), and arable land per capita (hectares per person) in the empirical model, following the previous studies (Ajanaku & Collins, 2021; Lokonon & Mounirou, 2019; Faria & Almeida, 2016; Yameogo, 2021; Ehrhardt-Martinez et al., 2002; Nathaniel & Bekun, 2020)

This study employed Pooled Mean Group (PMG). Before implementing PMG, this unit root and cointegration tests were included. Unit root test is critical to avoid pseudo-regression results. If the variables are proven to have unit roots, an estimation method that accounts for non-stationarity is required. This study chose the stationarity test proposed by Levin et al. (2002), i.e., LLC. It was assumed homogeneity of AR coefficients for all panel units. The equation for the unit root test can be written as follows:

$$\Delta Y_{it} = \alpha Y_{it-1} + \sum_{j=1}^{q_i} \beta_{it} \Delta Y_{it-j} + Z_{it}^{*} \delta + \varepsilon_{it} \text{ . (4)}$$

Where α=1-ρ. If $|\rho| < 1$, y is stationary. On the other hand, if $|\rho| = 1$, y contains the unit root. The null hypothesis is rejected if the t-statistic is greater than the critical value or the p-value is less than the 10% significance level. As a robustness check, this study performed a second-generation unit root test, the Cross-sectional Augmented version of IPS (CIPS) proposed by Pesaran (2007). CIPS test is appropriate for heterogeneous and cross-sectional dependence problems in the panel. Critical values can be accessed in Pesaran (2007).

The next step was the cointegration test. A cointegration test is critical if the variables are nonstationary at the level. This study implemented a test proposed by Kao (1999), Pedroni (1999; 2004), and (Westerlund, 2005). A cointegration is the transformation of nonstationary variables into stationary variables that are integrated in the same order. Kao (1999) employed DF and ADF statistics to check cointegration in various panel data, similar to the Engle-Granger standard and based on a residual test. It was assumed that there were specific intercepts for each individual (i), and the coefficients among panels were homogeneous in the first stage of the regression.

Next, PMG estimation was applied to examine the nexus between urbanization and deforestation. The PMG is proposed by Pesaran et al. (1999). PMG permits individual panels (slope and intercept) to be heterogeneous in the short term, but homogeneous in the long run. PMG is suitable for long panels (T > N) because it allows non-stationary data and accommodates heterogeniety (Pesaran et al., 1999). The PMG estimator has been used in several recent articles on environmental degradation, for instance, Attiaoui et al. (2017), Islam (2021), and Yusuf et al. (2020). The PMG or panel ARDL (p, q) model is represented by Eq. 5:

$$DEF_{it} = \sum_{j=1}^{p} \lambda_{ij} DEF_{it-j} + \sum_{j=0}^{q} \delta_{ij} X_{i,t-j} + \nu_i + \varepsilon_{it} \text{ ....(5)}$$

Where i = 1, 2,…N denotes cross-section and t = 1,2,…,T denotes times. j shows lag. X indicates a vector of explanatory variables (URB, URB2, GDP, OPEN, FDI, and APC). ν and ε represent the deterministic components and the error term, respectively. Next, the PMG equation with error correction term (ECT) can be formed by Eq. 6:

$$\Delta DEF_{it} = \psi_i\left[DEF_{i,t-1} - (\gamma_0 + \gamma_1 X_{it-1})\right] + \sum_{j=1}^{p-1} \lambda'_{ij} \Delta DEF_{it-j} + \sum_{j=0}^{q-1} \delta'_{ij} \Delta X_{it-j} + \nu_i + \varepsilon_{it} \text{ ....(6)}$$

Finally, a causality test was included in this study. When several variables are showed to be cointegrated, it is critical to consider the direction of causality (Nathaniel & Bekun, 2020). The panel data non-causality test proposed by Dumitrescu & Hurlin (2012) was employed too.

The Dumitrescu-Hurlin (DH) causality test has the advantage to allow the issue of cross-sectional dependence and heterogeneity panel, and it can be applied to various panel data structures, T > N or T < N. Granger's Wald statistic was utilized in DH causality. The general equation for the DH non-causality test is Eq. 7.

$$y_{it} = v_i + \sum_{k=1}^{k} \gamma_i^{(k)} y_{it-k} \sum_{k=1}^{k} \beta_i^{(k)} x_{it-k} + \epsilon_{it} \quad (7)$$

Where y and x are stationary research variables and cointegration is assumed to be evident. Subscript t, i, and k represent year, country, and lag order, respectively. The null hypothesis states that no causal relationship for each subgroup. Reject the null hypothesis will occur if there is a causal relationship in at least one subgroup of the panel. The average Wald statistic was used for hypothesis testing. H0 is rejected if the standardized z- or z-wald statistic is greater than the critical value of 10% (Lopez & Weber, 2017).

RESULTS AND DISCUSSION

This results and discussion chapter explains the non-linear relationship between urbanization and deforestation by controlling economic and demographic factors. It consists of statistical descriptive, unit root test, cointegration test, PMG short- and long-run estimation results, and panel causality tests. To begin the analysis, this empirical study displays descriptive statistics of the variable in Table 1. The values of the rate of deforestation range from 5.51% to -6.82%. The significant interval between the maximum and minimum value of deforestation indicated that it varies across countries and periods. In addition, the standard deviation which was higher than the mean represented high data variation.

Similarly, the maximum and minimum value of urbanization was significant, indicating that development in Southeast Asia changed over time and varied across territories. Nevertheless, the standard deviation lower than the mean indicated common data variation. For the control variables, the results showed that the standard deviation of foreign direct investment, arable land per capita, GDP growth, and trade openness index were below the mean, indicating low data variation.

Table 2. Statistic Descriptive

	Mean	Max	Min	SD
DEF	0.26	5.13	-6.82	1.06
URB	42.64	78.25	17.68	18.18
GDP	5.17	13.70	-13.13	3.89
FDI	4.02	16.26	-2.76	3.28
APC	0.13	0.34	0.01	0.09
OPEN	1.01	2.20	0.12	0.45

Source: Data processed, 2022

The results of the CIPS and LLC unit root tests are shown in Table 2. The CIPS test results revealed that all the variables reject the null hypothesis at the level, except for the openness index, at least at a 10% significance level. The CIPS unit root test reveals that the openness index is stationary at the first-order difference. Based on the CIPS and LLC unit root test, it can be concluded that variables in this paper are integrated into order one, i.e., I(1).

Table 3. The Unit Root Test Result

	LLC		CIPS	
	Level	Δ	Level	Δ
DEF	-4.19	-11.69**	-2.57**	-5.18***
GDP	-7.50	-17.50***	-2.56**	-5.21***
URB	-0.29	-4.86***	-2.69***	-1.66***
APC	-5.42**	-7.82***	-2.17*	-2.89***
OPEN	-3.52	-14.10***	-1.32	-4.26***
FDI	-6.29**	-13.60***	-2.39**	-5.12***

*p<10, **p<5, and ***p<1%

Source: Data processed, 2022

Next, this paper displays the cointegration test results in Table 3 for the nexus between deforestation and explanatory variables. All the statistical tests rejected the null hypothesis at a 5% significant level, except for Panel rho statistic. Variables in this study, i.e., deforestation, urbanization, and control variable, were concluded to move together toward long-run equilibriun, while cointegration was evident. All cointegration tests, i.e., Kao, Pedroni, and Westerlund, have confirmed the existence of a long-run relationship.

Table 4. Cointegration Test Result

		Statistic	**P-value**
Kao	MDF	-5.157***	0.000
	DF	-5.324***	0.000
	ADF	-2.213**	0.013
	Unadj. MDF	-10.977***	0.000
	Unadj. DF	-6.915***	0.000
Pedroni Common AR	Panel v	-1.954**	0.025
	Panel rho	0.994	0.160
	Panel PP	-3.250***	0.001
	Panel ADF	-3.093***	0.001
Pedroni Specific AR	Group rho	2.317**	0.010
	Group PP	-2.434**	0.008
	Group ADF	-2.252**	0.012
Westerlund	Variance ratio	-1.607**	0.054

Source: Data processed, 2022

presents the short- and long-run PMG estimation. In the short term, the empirical results showed that urbanization positively affected deforestation at a significance level of 10%. This result is in line with previous studies reported by Yameogo (2021) in Burkina Faso and Nathaniel & Bekun (2020) in Nigeria. An increase in urban population causes a decrease in forest cover. However, in the short run, a non-linear nexus between urbanization and deforestation is no evidence.

Other factors causing deforestation in the short run were arable land per capita and trade openness. These empirical findings designated that an increase in psychological density and trade openness drove forest depletion. A positive link between trade openness and deforestation in the short run is in line with studies by Nathaniel & Bekun (2020). Trade drives deforestation through the export of foresty and agricultural products (Defries et al., 2010; Ajanaku & Collins, 2021; Faria & Almeida, 2016)

Next, the short-run equation found that the ECT coefficient was negative and significant at the 1% level, indicating the presence of long-term equilibrium. The ECT (-1) coefficient of -0.59158 confirmed that about 59% correction towards long-run equilibrium was adjusted in a year following shocks to the economy.

Table 5. PMG Estimation Result

		Coefficient	**SE**	**t**	**p-value**
Long run equation					
	URB	0.07227***	0.02679	2.697	0.008
	URB2	-0.00056*	0.00031	-1.828	0.071
	GDP	0.00822**	0.00381	2.158	0.034
	FDI	0.02200***	0.00333	6.606	0.000
	OPEN	-0.27957***	0.02679	-10.436	0.000
	APC	-2.13870***	0.36343	-5.885	0.000
Short run equation					
Error Correction	ECT (-1)	-0.59158**	0.12006	-4.927	0.000
	ΔURB	7.33747*	4.07338	1.801	0.075
	ΔURB (-1)	-2.14037	3.86542	-0.554	0.581
	ΔURB2	-0.19359	0.17139	-1.130	0.262
	ΔURB2 (-1)	0.15057	0.17556	0.858	0.393
	ΔGDP)	-0.00106	0.00435	-0.244	0.808
	ΔGDP (-1)	0.00257	0.03945	0.065	0.948
	ΔFDI)	0.03371	0.05624	0.599	0.550
	ΔFDI (-1)	-0.01122	0.02579	-0.435	0.665
	ΔOPEN	0.19663	0.20120	0.977	0.331
	ΔOPEN (-1)	1.41790**	0.65466	2.166	0.033
	ΔAPC	35.13763**	14.98830	2.344	0.021
	ΔAPC (-1)	-4.79612	18.80745	-0.255	0.799
	Constant	-2.21161*	1.22307	-1.808	0.074

*,**, and *** indicates significant at 10, 5, and 1% level, respectively
Lags: PMG(1,2,2,2,2,2,2) based on AIC; Δ denotes first differentiaton
Source: Data processed, 2022

The long-run estimation revealed that the neux between urbanization and deforestation was non-linear. The coefficient value of β_1 was positive, while the β_2 was the opposite, negative, each with a significance level of 1% and 10%. These findings have confirmed that the relationship between urbanization and deforestation in Southeast Asia followed the inverted U-shaped, supporting the EKC and EMT hypotheses. The direction of the coefficients is in line with Ehrhardt-Martinez et al. (2002). This study, however, discovered that the turning point occurred when the national level of urbanization was 64.76%. We corrected and prosed specific turning points for Southeast Asia which was higher than the previous study by Ehrhardt-Martinez et al. (2002), which reports turning points of around 36%.

The inverted U-shaped represents that urbanization causes deforestation at the initial and acceleration stage. After a certain threshold (64.76%), urbanization supports national forest cover increase. In another sense, urbanization only causes deforestation in the early and first-moderate stages of economic development. Only Brunei and Malaysia have surpassed the 64.76 % threshold, with a national urbanization level of 78.25% and 77.16%, respectively. Meanwhile, other countries such as Indonesia, Thailand, Philippines, Vietnam, Myanmar, Cambodia, and Laos were still distant from a turning point. This condition implies that urbanization in Southeast Asia will continue to drive deforestation. Robust integration between urban green development and forest management is needed to tackle this situation.

$$T^* = \frac{-\beta_1}{2\times\beta_2} = \frac{-0.0727}{2\times -0.00056} = 64.76 \quad ....(8$$

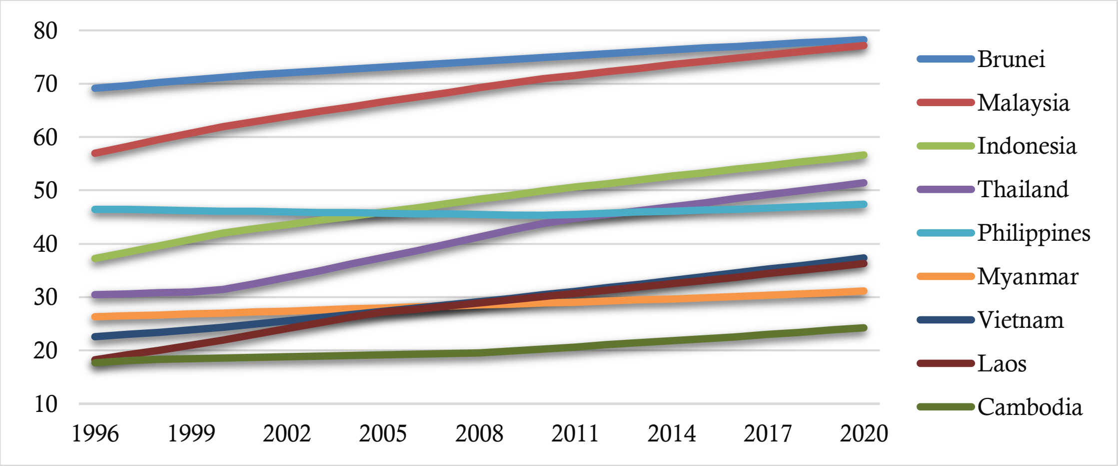

Figure 2. level of urbanization in Southeast Asia, 1996 – 2020
Source: WorldBank, 2022 (Processed)

Figure 2 displays Southeast Asia's urban population from 1996 to 2020. Urbanization trend in the Philippines and Cambodia was flat. It indicates that the rate of urbanization was low, i.e., rapid urbanization was not evident. In contrast, urban populations in Malaysia, Laos, Indonesia, and Thailand showed uptrends, representing rapid urbanization has occurred. Referring to the PMG estimation results, we considered that Malaysia, Indonesia, Laos, and Thailand had a significant role in forest loss. As mentioned, urbanization contributes to deforestation through agriculture based-consumption and city expansion (Prugh, 2016).

The deforestation rate in Southeast Asia has been remarkable and widely discussed. During 1996 – 2020, Vietnam experienced a significant increase in forest cover. In contrast, other countries were floundering to resolve the deforestation issues. Indonesia, Cambodia, and Maynmar were the regions with the magnificent forest cover loss, 16.28%, 16.64%, and 16.36%, respectively.

Next, we reported the control variables. Economic development was another cause of deforestation. Economic development is another cause of deforestation. At the 10% level, GDP growth positively affected long-run deforestation. This finding contradicts the results of Nathaniel & Bekun (2020) and Yameogo (2021) which discovered that GDP per capita only does cause short-term deforestation. Another finding, FDI had a positive effect on deforestation at a 5% significance level. These results are consistent with the previous study in Sub-Saharan Africa (Lokonon & Mounirou, 2019). These findings supported the Pollution Haven Hypothesis. Foreign direct investment not only serveed as an engine of growth, but also harmed forest resources. Strong integration of sustainable investment and forest management is needed to tackle this evidence.

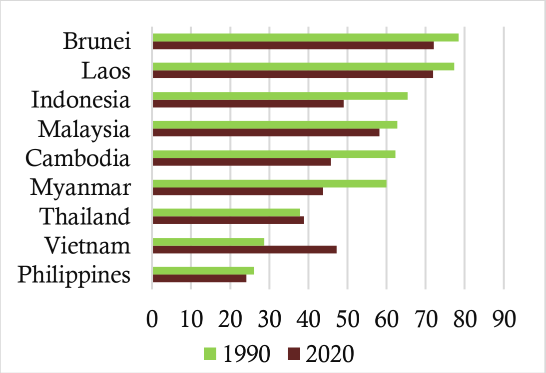

Figure 3. Southeast Asian forest cover (% of land) in 1990 and 2020

Source: WorldBank, 2022 (Processed)

Surprisingly, the long-term estimate found a negative impact of trade openness and arable per capita on deforestation, each at a significance level of 1%. These results are inverse to previous study reported by Faria & Almeida (2016) and Kustanto (2022). Nevertheless, these results are in line with studies reported by Maji (2017) and Nathaniel & Bekun (2020). Trade openness supported forests to improve through comparative advantages. Moreover, an analysis for specific countries potentially has a different result. For instance, Tsurumi & Managi (2014) found that trade opennes drive deforestation in non-OECD countries. Practically, the composition of trade in each country is different. A region with farming export oriented may drive deforestation through trade. In contrast, a service trade-oriented nation did not cause any empirical degradation.

A negative relationship between arable land per capita, i.e., psychological density, and deforestation in the long run is inverse with the previous studies by Nathaniel & Bekun (2020) and Yameogo (2021). This paper reports that demographics factor was not the prominent driver of deforestation in long run. An increas in density did not stimulate in an crease farming land through deforestation. A negative impact of arable land per capita on deforestation might be because households in Southeast Asia have shifted from agriculture-based livelihood to industrial employmees.

Table 6. DH Causality Result

H0: x does not homogenouse cause y	**W-Stat.**	**Zbar-Stat.**
URB → DEF	9.423	8.435***
DEF → URB	5.926	4.322***
GDP → DEF	6.980	5.562***
DEF → GDP	2.112	-0.162
FDI → DEF	2.703	0.533
DEF → FDI	1.377	-1.027
OPEN → DEF	3.013	0.897
DEF → OPEN	1.926	-0.381
APC→ DEF	7.384	6.037***
DEF → APC	5.902	4.294***
GDP → URB	5.635	3.981***
URB → GDP	5.462	3.777***
FDI → URB	7.338	5.983***
URB → FDI	7.686	6.392***
OPEN → URB	2.634	0.452
URB → OPEN	19.287	20.034***
APC → URB	4.111	2.189**
URB → APC	5.479	3.797
FDI → GDP	3.025	0.912
GDP → FDI	3.826	1.854*
OPEN → GDP	1.087	-1.368
GDP → OPEN	4.627	2.796***
APC → GDP	3.538	1.514
GDP → APC	1.712	-0.633
OPEN → FDI	3.401	1.353
FDI → OPEN	2.348	0.115
APC → FDI	3.361	1.306
FDI → APC	1.537	-0.838
APC → OPEN	12.295	11.812*
OPEN → APC	3.085	0.982

→ Represents the direction of causality.

Lags: 2 (recommendation AIC and HC)

Source: Data Processed, 2022

Next, the bidirectional causality between urbanization and deforestation indicated that a change in urban population caused a change in forest cover, and vice versa. The result is in line with Yameogo (2021). Deforestation generates urban growth. The feedback effect was evident. The result suggested that urban and forest management policies should improve simultaneously to tackle the damaged connection between urbanization and deforestation.

CONCLUSION

Urbanization shifts the economic structure from agricultural based-production to industrial and drives the population to live in an urban area. It also generates a chance for economic growth through human capital accumulation. Nevertheless, uncontrol rapid urbanization and unsophisticated urban policies will depress green land neighborhoods, for instance, urban sprawl and leapfrog. Moreover, urban dwellers are more consumptive rather than rural communities, so it potentially drives forest conversion for livestock and cropland. This study examined the impact of urbanization on deforestation in the short- and long-run as well as investigates potential non-linear nexus. PMG estimation and DH causality were applied to examine the variables.

The cointegration test revealed that long-run equilibrium is evident. The result has confirmed that urbanization drives deforestation in the short- and long run. Furthermore, in the long run, this study uncovers a non-linear relationship between urbanization and deforestation, following an inverted U-shape. Initially, urbanization drives deforestation, but after a particular turning point, it causes forest cover to increase. The turning point occurs when the urbanization level reached 64.76%, i.e., the moderate development stage. Only Malaysia and Brunei Darussalam are two developing countries with a level of urbanization greater than the threshold. Other countries, such as Indonesia, Thailand, Cambodia, Myanmar, Vietnam, the Philippines, and Laos, are distant from the turning point, with urbanization levels of 56.64%, 51.42%, 47.41%, 37.34%, 36.29%, 31.14%, and 24.23%, respectively. In addition, the study revealed bidirectional causality between deforestation and urbanization. In case southeast Asia is still dominated by low-level urbanization, we suggest that rural-urban migration and urban population growth in Southeast Asia continue to drive deforestation in these decades. Strong links between urban development policies, national development agenda, and forestry governance are required to ensure that urbanization does not reduce national forest cover.

Since the nexus between urbanization and deforestation are bidirectional causalities, policies from two features, forest and urban, are strongly required. Based on empirical findings, we suggest that countries with low levels of urbanization, i.e., below the threshold of 64.76%, should construct robust environmental policies related to forest resources and promote sustainable urban development. Based on the deforestation aspect, forest certification, regulation, and conservation are vital in this case. In terms of the urbanization dimension, programs that meet the principle of green growth and have low potential to depress forest resources are urban land use efficiency, compact city, vertical city, and urban farming.

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