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THE NEXUS BETWEEN URBANIZATION, LIVESTOCK, AND DEFORESTATION IN SOUTHEAST ASIA: EVIDENCE FROM PMG AND PANEL-CAUSALITY

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ABSTRACT

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Southeast Asia is one of the regions that has received a red report card related to forest management. This article intends to investigate the relationship between urbanization, livestock, and deforestation in Southeast Asia, as well as elaborate on STRIPAT's concept. This study uses panel data from 9 countries and 28 periods, obtained from the statistical publication of WDI, World Bank. This article applies the Pooled Mean Group (PMG) estimation and performs unit root, co-integration, and causality tests. The estimation results show that urbanization, GDP per capita, and livestock positively and significantly impact deforestation. The increase in the level of urbanization, GDP per capita, and livestock production will be followed by a decrease in forest cover area. In contrast, population density is not the driver of deforestation. In addition, this paper confirms bidirectional causality between urbanization and deforestation rates, as well as a unidirectional causality from income per capita to deforestation and from population density to deforestation. National development plans, urban development, and livestock expansion must be integrated with forest management to reduce deforestation rates.

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1. INTRODUCTION

Deforestation is still an environmental issue that has not been resolved by countries in the tropics, for example, in Southeast Asia. During the period 1990 to 2020, the forest cover area in Southeast Asia decreased by 376,000 km2, more than the mainland of Thailand, Myanmar, and Cambodia [1]. The existence of forest depletion in Southeast Asia will become a severe problem, both on a local and global scale, because tropical forests have an essential role in achieving sustainable development. Tropical forests are carbon sinks and are home to terrestrial biodiversity. Based on the World Bank statistical report, only Vietnam and Thailand experienced increasing forest cover [2]. Since 1990, the trend of national forest cover in Vietnam and Thailand has expanded significantly, representing that the reforestation rate is higher than the rate of deforestation. In contrast, the national forest cover in Brunei Darussalam, Indonesia, Laos, Cambodia, Myanmar, Malaysia, and the Philippines has decreased significantly, -6.26%, -16.37%, -5.41%, -16.64%, -16.28%, -4.58%, and -1.92%, respectively [2].

Forest degradation has long been associated with agents, driving factors, and the existence of environmental policies. The drivers of deforestation are divided into two; proximate (direct) and underlying (indirect). The proximate factors incorporate agricultural expansion, infrastructure development, and timber extraction. The underlying factors are economic, demographic, institutional, political, technological, social, and cultural aspects, i.e., the roots of forest cover change [3].

Since the 21st century, urbanization has been considered a crucial cause of forest degradation in the tropics. Urbanization drives deforestation through the consumption of agricultural commodities and urban development [4]. Urbanization leads to changes in lifestyle and diet, causing an increase in food demand, thereby driving the conversion of forests to agricultural land. The increase in urban population through urbanization also depresses land resources, causing forest fragmentation around cities.

Another factor is livestock production has been considered an important cause of deforestation. Beef production is responsible for 41% of tropical forest depletion [5]. The increase in demand for meat has led to an increase in the scale of livestock production and turn, has caused the conversion of forests to grazing. Grassland expansion for livestock in Tanzania, Central America, and South America is proven to be causing deforestation [6], [7].

Based on the proposed premise, this empirical study intends to investigate the relationship between urbanization, livestock, and deforestation within the framework of the STRIPAT model for Southeast Asia. This article uses panel data for the period 2001 to 2018. To the best of the author's knowledge, an investigation of deforestation using the SRTIPAT model and econometric approach has yet to be conducted for the specific region of Southeast Asia. In addition, this study also examines the impact of livestock production, which is still ignored in previous studies. This article answers the research question using a heterogeneous panel (PMG) proposed by Pesaran [8]. The advantage of PMG is allowing heterogeneous slope and intercept in the short term, but it is assumed to be homogeneous in the long run [8]. The PMG is suitable for long-panel applications because it allows different degrees of stationery.

2. RESEARCH METHODS

2.1 Model Specification

This paper intends to investigate the relationship between urbanization, livestock, and deforestation rates in Southeast Asia, and elaborate on the framework of the STRIPAT Model. The data used is a cross-country panel for the period 2001 – 2018. The STRIPAT model explains that environmental impacts are caused by population, welfare, and technology factors [9]. The STRIPAT model can be written using **Equation (1)**.

$$I = aP^{b}A^{c}T^{d} \quad (1)$$

Transformation to logarithmic form, then we get **Equation (2)**.

$$I = \alpha + bP_{it} + cA_{it} + dT_{it} + e_{it} \quad (2)$$

where I, P, A, and T are environmental degradation, population, affluence, and technology, respectively. e is the error term. The environmental degradation referred to in this study is deforestation. Assuming the technological factor induces the error term, **Equation (2)** can be modified and expanded by adding the factors of urbanization and livestock production. **Equation (3)** is our empirical model.

$$Def_{it} = \beta_0 + \beta_1 \ln(GDP)_{it} + \beta_2 \ln(POP)_{it} + \beta_3 \ln(URB)_{it} + \beta_4 \ln(LVSK)_{it} + \varepsilon_{it} \qquad (3)$$

where DEF is deforestation, GDP is income per capita, POPDEN is population density, and LVSK is an index of livestock production. The subscripts t and i are the analysis period (2001 to 2018) and country, respectively. This article uses the definition of deforestation in a narrow sense, namely the change in forest cover area. Deforestation is proxied using the net change in forest cover area. **Equation (4)** describes the method of measuring deforestation **[10]**.

$$DEF = FC_{it-1} - FC_{it} \qquad (4)$$

FC is forest cover (%). If the DEF value is positive, then deforestation occurs, i.e. the area of forest cover in the year of t is lower than the previous year (t-1). Operational definitions for other variables are presented in **Table 1**.

Table 1. Research Variables

	Definition	β Expectation	Source
Deforestation (DEF)	Net change in forest cover		WDI
Income per capita (GDP)	Income per capita (constant 2015 US$)	+	WDI
Population Density (POPDEN)	Total population per square kilometers	+	WDI
Urbanization (URB)	Percentage of population living in urban areas	+	WDI
Livestock (LVSK)	Livestock production index	+	WDI

2.2 Data

This research uses secondary data from a cross-country panel in Southeast Asia, period 2001 – 2018. The objects of study are nine developing countries, namely Indonesia, Malaysia, Brunei Darussalam, Thailand, Laos, Vietnam, Cambodia, and Myanmar. The length of the reservation refers to the availability of data on the area of forest cover. All data in this study, namely forest cover, GDP per capita, population density, level of urbanization, and livestock production index, were obtained from the statistical publication of World Development Indicators (WDI) published by the World Bank. The total observations were 162 units, consisting of 18 series and 9 cross-sections.

2.2 Estimation Method

This paper employs the Pooled Mean Group (PMG) or Panel ARDL estimation method to investigate the relationship between urbanization, livestock, and deforestation in Southeast Asia within the framework of the STRIPAT model. This study is equipped with unit root and cointegration tests. The unit root test is important in order to tackle spurious regression and see the degree of integration of variables. The PMG method requires the data to be stationary at the first level of differentiation. For unit root detection, this study applies the LLC stationarity test. This detection assumes individual homogeneity (slope and intercept) in the first stage regression **[11]**. The standard LLC unit root test can be described by **Equation (5)**.

$$\Delta Y_{it} = (1-\rho)Y_{it-1} + \sum_{j=1}^{q_i} \gamma \Delta Y_{it-j} + X_{it}^{*}\delta + \varepsilon_{it} \qquad (5)$$

Y_{it} is the research variable, Δ = differentiation, q is the amount of ADF regression lag, θ is the coefficient, and ε_{it} are error terms. LLC assumes homogeneity of autoregressive coefficients on individual panels ($\rho = \rho_i$). Y is stationary if only if $|\rho| < 1$. Adopting the first lag, the unit root test process for each variable is as follows **[12]**.

Deforestation

$$\Delta DEF_{it} = \alpha DEF_{it-1} + \gamma\left(\Delta DEF_{it-j}\right) + X_{it}^{*}\delta + \varepsilon_{it} \qquad (6)$$

Income per capita

$$\Delta \ln(GDP)_{it} = \alpha \ln(GDP)_{it-1} + \gamma\left[\Delta \ln(GDP)_{it-j}\right] + X_{it}^{*}\delta + \varepsilon_{it} \quad (7)$$

Population density

$$\Delta \ln(POP)_{it} = \alpha \ln(POP)_{it-1} + \gamma\left[\Delta \ln(POP)_{it-j}\right] + X_{it}^{*}\delta + \varepsilon_{it} \quad (8)$$

Urbanization

$$\Delta \ln(URB)_{it} = \alpha \ln(URB)_{it-1} + \gamma\left[\Delta \ln(URB)_{it-j}\right] + X_{it}^{*}\delta + \varepsilon_{it} \quad (9)$$

Livestock

$$\Delta \ln(LVSK)_{it} = \alpha \ln(LVSK)_{it-1} + \gamma\left[\Delta \ln\,(LVSK)_{it-j}\right] + X_{it}^{*}\delta + \varepsilon_{it} \quad (10)$$

Reject the null hypothesis if the t-statistic is higher than the critical value or p-value is less than the 10% significance level. As a robustness check, this empirical article presents the IPS and CIPS stationarity tests. The advantage of IPS is that it accommodates the issue of heterogeneity of individual panels, while the advantage of CIPS is that it accommodates the issue of cross-sectional dependence [13] [14].

After detecting the unit root, this article presents the cointegration test. This paper implements Kao residual cointegration test [15]. Cointegration indicates a long-term relationship, which is a combination of some variables that are not stationary to be stationary and are integrated in the same order. If some variables are not stationary but cointegrated, then spurious regression can be eliminated. The Kao cointegration test assumes homogeneity of slope and intercepts in the first stage of regression [15].

$$y_{it} = \alpha_i + \beta x_{it} + e_{it} \quad (11)$$

where:

$$\hat{e}_{it} = \rho \hat{e}_{it-1} + u_{it} \quad (12)$$

$\hat{e}_{it}$ is the residual of the equation, y and x are cointegrated if $\rho < 1$. Reject the null hypothesis if the t-statistic is greater than the t-table or the p-value is lower than the 10% significance level. As a robustness check, this study is equipped with the Pedroni [16] and Westerlund cointegration test [17]. The advantage of the Pedroni cointegration test is that it allows intercept heterogeneity and adds trend [17].

Furthermore, this empirical paper applies the PMG estimation method proposed by Pesaran [8]. PMG accommodates the issue of heterogeneity of panel data, allowing different slopes and intercepts between individuals in the short term, but is assumed to be homogeneous in the long run [8]. PMG is also suitable for long panels because data with the time-series dimension (T) is larger and the cross-section (N) tends to be non-stationary at the level. Estimator PMG uses maximum likelihood, assumes the error is normally distributed, and implements the Newton-Raphson optimization algorithm. Several recent studies also apply the PMG method. Islam [18] used PMG to test the EKC framework in South Asia. Vebic et al. [19] applied PMG to estimate the connection between urbanization, GDP per capita, energy consumption, and pollution in Southeastern Europe. Sheng & Guo [20] employed MG and PMG to see the effect of urbanization on carbon dioxide in China. The ARDL (p, q) or PMG panel standard in this article is Equation (13).

$$DEF_{it} = \sum_{j=1}^{p} \lambda_{ij} DEF_{it-j} + \sum_{j=0}^{q} \delta_{ij}\, X_{i,t-j} + \nu_i + \mu_{it} \quad (13)$$

where i = 1, 2,…, N denotes the cross-section, t = 1,2,…, T denotes the period (year), X is a vector of explanatory variables, ν_i is a fixed effect, j is lag, and μ_{it} is the error term. To check the short- and long-run dynamic, Equation (13) is re-parameterization as follows [21]:

$$\Delta DEF_{it} = \eta_i DEF_{it-1} - \vartheta_i X_{it} + \sum_{i=1}^{p-1} \lambda'_{ij} \Delta DEF_{it-j} + \sum_{j=0}^{q-1} \delta'_{ij}\, \Delta X_{it-j} + \nu_i + \mu_{it} \quad (14)$$

where:

$\eta_i = -1\left(1 - \sum_{j=1}^{p} \lambda_{ij}\right);$

$\vartheta_i = \sum_{j=1}^{p} \delta'_{ij}$;

$\lambda'_{ij} = -\sum_{m=j+1}^{p} \lambda_{im}, j = 1,2 \dots p-1$; and

$\delta'_{ij} = \sum_{m=j+1}^{q} \delta'_{im}, j = 1,2 \dots q-1$;

Equation (14) can be rearranged into **Equation (15)** to examine the error correction term.

$$\Delta DEF_{it} = \psi_i [DEF_{i,t-1} - (\gamma_0 + \gamma_i X_{it-1})] + \sum_{j=1}^{p-1} \lambda'_{ij} \Delta DEF_{it-j} + \sum_{j=0}^{q-1} \delta'_{ij} \Delta X_{it-j} + v_i + \mu_{it} \quad (15)$$

where $\gamma_i = -\left(\sum_{j=0}^{q-1} \frac{\vartheta_{ij}}{\psi_i}\right)$, λ and δ are the short-term coefficient vectors of the lags of the independent and dependent variables, while γ_i are the long-term coefficient vectors, and ψ is the coefficient of ECT. For verification ψ, it should be negative (-1 to 0) and significant. ψ presents the speed of convergence towards long-run equilibrium. -1 confirms immediate adjustment to the long-term equilibrium for shock in period t_{-1} and 0 indicates no evidence [22].

Finally, this study adds a causality test. It is meaningful to investigate the direction of causality when variables are shown to be cointegrated [23]. This article applies the DH non-causality test suggested by Dumitrescu & Hurlin [24]. The advantage of the DH non-causality test is that it permits cross-sectional dependence and panel data heterogeneity problems. The DH non-causality test adopted the Wald statistic. **Equation (16)** is the general model of the panel causality test.

$$y_{it} = v_i + \sum_{k=1}^{m} \beta_i^{(m)} y_{it-k} \sum_{k=1}^{m} \alpha_i^{(m)} x_{it-k} + \epsilon_{it} \quad (16)$$

x_i and y_{it} are stationary and co-integrated variables, t and i represent the period (2001 – 2018) and specific countries, e is the error term. m is lag order. The null hypothesis is no causal relationship for any subgroups. Reject the null hypothesis if there is a causal relationship, at least one subgroup.

$H_0: \forall, \alpha_i = 0$, for $i = 1, \dots N$

and

$H_1: \exists, \alpha_i \neq 0$, for $i = 1, \dots N$

The DH non-causality test was carried out based on the average Wald statistical value:

$$W_{N.T}^{HNC} = N^{-1} \sum_{i=1}^{N} W_{i,T} \quad (17)$$

$W_{i,T}$ is the value of the individual wald statistic. The hypothesis test adopts the standardized $\bar{z}$- and $\tilde{z}$-wald statistics. Reject H0 if the $\bar{z}$ or $\tilde{z}$ is greater than the critical value at the 10% level.

3. RESULTS AND DISCUSSION

3.1. Summary Statistic Descriptive of Variables

Table 2 displays descriptive statistics of research variables. All variables are modified into a natural log form, except deforestation. The distribution of all variables was found to be non-normally distributed, except for ln (POPDEN). The net deforestation of Southeast Asian countries for the period 2001 - 2018 ranges from -2.419% to 0.178% per year. The standard deviation of DEF is higher than the mean value, indicating high data variation. On the other hand, the standard deviations of ln(GDP), ln(POPDEN), ln(URB), and ln(LVSK) are lower than the mean value. DEF, ln(GDP), and ln(URB) have a positive skew, while ln (POPDEN) and ln(LVSK) have a negative skew. The distribution of DEF and ln (LVSK) data followed the leptokurtic form, while ln(GDP), ln(POPDEN), and ln(URB) followed the platykurtic form.

Table 2. Statistic Descriptive of Research Variables

	DEF	Ln (GDP)	Ln (POPDEN)	Ln (URB)	Ln (LVSK)
Mean	0.163	7.976	4.655	3.686	4.455
Maximum	1.974	10.476	5.880	4.352	4.722
Minimum	-1.019	5.843	3.154	2.929	3.565
Std. Dev.	0.469	1.153	0.710	0.418	0.251
Skewness	1.700	0.728	-0.122	0.041	-1.742
Kurtosis	8.546	2.908	2.667	1.926	5.631
Prob.	0.000	0.001	0.563	0.020	0.000

3.2. The Panel Unit Root Test Result

Table 3 displays the results of the LLC, IPS, and CIPS unit stationarity tests. According to the results of the LLC unit root test, ln (POPDEN) failed to reject the non-stationary hypothesis at the level, while the DEF, ln(GDP), ln(LVSK), and ln (URB) were stationary at the level. Nevertheless, all variables are stationary at the first differentiation. Next, the results of the IPS test found that only ln(POPDEN) was stationary at the level and the results of the CIPS test found that only DEF was stationary at the level. However, LLC and CIPS confirmed that all variables were stationary at the first differentiation. The results of the LLC, IPS, and CIPS tests prove that DEF, GDP, POPDEN, LVSK, and URB are integrated in the first order, I(1).

Table 3. The Unit Root Test Result

Variable	LLC		IPS		CIPS	
	Level	**Δ**	**Level**	**Δ**	**Level**	**Δ**
DEF	-3.2077***	-9.5533***	-1.5956	-4.4947***	-3.285***	-3.458***
Ln(GDP)	-2.3989**	-6.8302***	-0.6739	-2.9468***	-2.043	-2,383**
Ln(POPDEN)	-0.1655	-4.7415***	-6.4133***	-2.5661***	-1.506	-2,417*
Ln(LVSK)	-4.5069***	-1.E+05***	-1.7134	-4.9861***	-2010	-2.842***
Ln(URB)	-5.3385***	-8.3894***	-1.8703	-3.5813***	-2.080	-3.447***

Δ denotes first difference operator
*p<10, **p<5, and ***p<1%

3.3. The Panel Co-integration Test Result

After the unit root test, this article displays the cointegration test outcomes in Table 4. The result of the Kao residual test (ADF-stat) confirms the rejection of the null hypothesis. This finding indicates that all the variables move together toward long-run equilibrium. The Pedroni and Westerlund cointegration tests also reject the null hypothesis of no cointegration. The long-run equilibrium between deforestation, urbanization, livestock, GDP, and population density is evident. These findings meet the requirements for using the PMG estimation method.

Table 4. Cointegration Test Results

		Statistic	**p-value**
Kao	MDF-stat.	-1.1840	1.1182
	DF-stat.	-1.5476*	0.0609
	ADF-stat.	1.8180**	0.0345
Pedroni	Group rho-stat	2.5693**	0.0051
AR (specific)	Group PP-stat	-2.3698***	0.0089
	Group ADF-stat	-2.2808**	0.0113

Pedroni	Panel v-stat	-2.5819***	0.0049
AR (same)	Panel rho-stat.	1.3907*	0.0822
	Panel PP-stat.	-2.8631***	0.0021
	Panel ADF-stat.	-2.7406***	0.0031
Westerlund	Variance ratio	-1.5555*	0.0599

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

3.4. The PMG Estimation Result

Table 5 presents the results of short and long-term PMG estimates for investigating the relationship between urbanization, livestock, and deforestation in the STRIPAT model framework. Based on the results of lag selection using Akaike Information Criteria (AIC), PMG (2,2,2,2) is the best model. In the long term, per capita income, livestock production, and urbanization have a positive effect on deforestation, each at a significance level of 1%, 1%, and 1%. On the other hand, population density has a negative effect on deforestation at a significance level of 1%.

The results of the PMG estimate confirm that urbanization in the period 2001 – 2018 in Southeast Asia has led to a decrease in forest cover area. The positive impact of urbanization on deforestation is in line with the arguments put forward by Prugh [4]. Urbanization causes the depletion of forests by increasing the demand for agricultural commodities and expanding the size of cities. Urbanization changes people's lifestyles to become more consumptive, thus forcing the conversion of forests to agricultural land [4]. This empirical finding is also in line with previous investigations in Burkina Faso and Nigeria [25][23]. The drivers of deforestation have shifted from farmers and villagers to plantation expansion, industrialization, and urbanization [26].

Table 5. Short and Long-run PMG Estimates

		Coefficient	Std. Error	t-Statistic	p-value
Long Run Equation	Ln(GDP)	0.37113***	0.02711	13.689	0.000
	Ln(POPDEN)	-8.40614***	0.61227	-13.729	0.000
	Ln(URB)	3.12080***	0.47843	6.523	0.000
	Ln(LVSK)	0.13848***	0.04653	2.976	0.004
Error Correction	ECT-1	-0.81746*	0.43974	-1.859	0.068
Short Run Equation	Δ(ARD(-1))	0.27033***	0.07592	3.561	0.001
	ΔLn(GDP)	-0.55076	1.90903	-0.289	0.774
	ΔLn(GDP(-1))	-0.01774	5.64894	-0.003	0.998
	ΔLn(POPDEN)	98.33427	111.43550	0.882	0.381
	ΔLn(POPDEN(-1))	-41.65832	55.34694	-0.753	0.455
	ΔLn(URB)	-247.94680	158.66390	-1.563	0.124
	ΔLn(URB(-1))	17681370	131.91800	1.340	0.185
	ΔLn(LVSK)	0.09869	0.69557	0.142	0.888
	ΔLn(LVSK(-1))	-0.31850	0.62844	-0.507	0.614
Constant		17.87399	11.93551	1.498	0.140
	Sum squared residual	0.32577			
	Log likelihood	338.0958			

Δ denotes first difference operator
*p<10, **p<5, and ***p<1%

Another finding of this empirical study also confirms that livestock has a positive and significant effect on the net deforestation rate in the long term. These results are in line with study results in Amazon and Tanzania [6] [7]. Livestock production drives deforestation through the expansion of grazing and land for animal feed production. This condition indicates the need for the application of technology in the livestock sector to encourage efficiency to reduce the rate of deforestation. In addition, land management is crucial to mitigate livestock impacts on forest resources.

Regarding factors of population and affluence, the positive impact of per capita income on deforestation is in line with the hypothesis that income drives environmental degradation. An increase in per capita income will encourage an increase in demand for forestry and agricultural commodities, thereby pushing farming expansion and timber extraction. Agricultural expansion in Southeast Asia is executed by converting forests. Referring to the Environmental Kuznets Curve (EKC), the positive impact of GDP per capita on deforestation indicates that Southeast Asian countries are still at the early stage of development. The relationship between GDP and deforestation has not yet reached a turning point.

Next, the negative impact of population density on deforestation is not in line with the SRTIPAT model. The population is not the driver of deforestation. This result is also not in line with the Neo-Malthusian hypothesis that population increase promotes environmental degradation. On the other hand, the results of the study show that the increase in population density leads to an increase in forest cover area. This finding is in line with the study in Burkina Faso [25]. Empirical evidence suggests that deforestation in Southeast Asia is caused by economic factors, not demographics.

Finally, the long-term estimation results must be confirmed through the short-term equation. The ECT coefficient value was found to be negative and significant. This finding suggests that shocks in the short term will be adjusted by several explanatory variables (GDP, POPDEN, URB, and LVSK) toward long-term equilibrium. These results also confirm that a long-term relationship is evident.

3.5. Panel Causality Test Result

Table 6 displays the results of the Dumitrescu-Hurlin [24] non-causality test. Regarding the aspect of forest resources, the results of the non-causality test found a one-way causality relationship from GDP to DEF, POPDEN to DEF, and a two-way causality relationship between URB and DEF. The bidirectional causality between URB and DEF indicates that changes in the percentage of the population living in cities will cause changes in forest cover area, and vice versa. Meanwhile, the one-way causality from per capita income to deforestation indicates that forest degradation is not the source of the increase in per capita income. Outside the forestry context, this study found bidirectional causality between GDP and POPDEN, GDP and URB, POPDEN and URB, POPDEN and LVSK, and URB and LVSK. Finally, this study finds a one-way causality from GDP to LVSK.

Table 6. Panel Causality Test Result

H0: x does not homogeneously cause y	W-Statistic	Zbar-Statistic	p-value
GDP → DEF	4.5326*	2.0443	0.0409
DEF → GDP	2.8693	0.4159	0.6775
POPDEN → DEF	9.0587***	6.4755	0.0000
DEF → POPDEN	3.1735	0.7138	0.4754
URB → DEF	23.4308***	20.5462	0.0000
DEF → URB	16.8429***	14.0964	0.0000
LVSK → DEF	2.9896	0.5338	0.5935
DEF → LVSK	2.5986	0.1510	0.8800
POPDEN → GDP	8.1089***	5.5457	0.0000
GDP → POPDEN	8.3619***	5.7934	0.0000
URB → GDP	6.5046***	3.9750	0.0001
GDP → URB	13.3178***	10.6453	0.0000
LVSK → GDP	2.1347	-0.3033	0.7617

GDP → LVSK	4.1582	1.6778	0.0934
URB → POPDEN	28.8948***	25.8956	0.0000
POPDEN → URB	9.1634***	6.5780	0.0000
LVSK → POPDEN	17.2557***	14,5006	0.0000
POPDEN → LVSK	5.4836***	2.9754	0.0029
LVSK → URB	6.1066***	3.5854	0.0003
URB → LVSK	4.1428*	1.6627	0.0964

Lags: 2 (recommendation AIC, SC, and HQ through VECM test)
→ denotes the direction of causality.
*p<10%, **p<5%, and ***p<1%

4. CONCLUSIONS

Deforestation is still a Southeast Asian environmental issue that has not been able to be resolved. The drivers of deforestation in the 21st century are more complex, covering economic and demographic aspects. This empirical article intends to investigate the relationship between livestock production, urbanization, and deforestation in Southeast Asia, as well as elaborate on STRIPAT's concept. This paper employs the PMG estimation and panel causality method. The estimation result confirms that livestock, urbanization, and GDP per capita are the drivers of deforestation in Southeast Asia. On the other hand, population density is not a driver of deforestation. The increase in the level of urbanization, livestock production, and per capita income drives forest depletion. In addition, panel non-causality tests confirm the two-way relationship between urbanization and deforestation, as well as the one-way causality from income per capita toward deforestation and from population density toward deforestation. It is needed advancement in livestock production technology, urban governance, and national sustainable program to reduce deforestation.

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