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The role of Socio-Economic Development after COVID-19 and Energy-Growth- Environment in ASEAN Economies

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Abstract: The present study assesses the energy-growth-environment nexus by including the effects of socio-economic development in ASEAN economies – a literature vacuum that needs to be filled. For this objective, panel data of 8 ASEAN nations throughout the 2000-2020 timeframe is obtained to examine the effect of human development, urbanization, and industrialization on energy-growth-environment interaction. Empirical estimation is carried out by adopting the second generation Cross Sectionally Augmented Autoregressive Distributed Lag Model (CS-ARDL) as the data's cross-sectional dependence and slope heterogeneity are present. It is observed that human development has a considerable negative influence on the environment and a significant positive impact on economic growth but has minimal effect on energy consumption. Urbanization and industrialization are the primary drivers of CO2 emission and energy consumption. However, urbanization does not affect economic growth considerably in ASEAN countries. Based on the findings, chosen countries are encouraged to invest more in human development measures, the transition towards zero-emission industrial variety, energy transition, and energy-efficient production technology.

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1. Introduction

Climate change and its considerable negative consequences on the environment are, without a doubt, one of the world's gravest problems (Nawaz et al., 2021). In recent decades, human activity, particularly energy use, has been identified as one of the primary causes of climate change. Energy is the fundamental driver of economic growth and is highly utilized due to the world's rapid urbanization. Without energy, there would be no living processes. In recent decades, however, there has been much discussion about the relationship between environmental degradation, economic growth, and energy consumption (Chien et al., 2022; Chontanawat, 2020), and larger CO_2 emissions and environmental damage are proven to be caused by massive energy consumption and higher levels of economic growth worldwide (Bakhtyar et al., 2017; S. Hanif et al., 2022). The same holds for Southeast Asian (ASEAN) nations. The ASEAN region has had around 4% annual economic growth over the previous three decades, one of the world's fastest rates. Rising affluence, expanding population, and urbanization have contributed to that region's energy consumption. Between 1995 and 2017, energy consumption increased by 3.4% per year (Khezri et al., 2022). ASEAN is a region that has had rapid economic and population expansion despite its high energy dependence, the recent increase in energy consumption, and resulting pollution emissions. Constant urban development has altered lifestyles and elevated individual living standards, resulting in a substantial rise in energy usage. The combustion of fossil fuels meets ninety percent of the ASEAN's energy demands. This has led to concerns that the rapid growth of these economies, which high energy consumption rates have supported, may be a factor in greenhouse gas (GHG) emissions and eventual climate change (Munir et al., 2020; Nawaz et al., 2020). Understanding the interrelationships between energy consumption, environmental quality, and economic growth in ASEAN economies is therefore quite intriguing and urgent (Chontanawat, 2020; Hussain et al., 2021; Mohsin et al., 2021).

The issue of the relationship between economic growth, energy use, and the environment has been widely addressed in the available literature. Numerous studies have examined the relationship between the environment, economic growth, and energy use in various nations, periods, variable variables, and econometric methodologies (Chen et al., 2018; I. Hanif, 2017; A. Khan et al., 2020; Mohsin et al., 2021; Pandey et al., 2020). Yet, no articles have examined how socio-economic development influences the growth- environment -energy consumption nexus. Better socio-economic development is desirable for social welfare and the standard of living. The major objective of every nation is to sustain and maintain a higher degree of economic development to support a healthy economy, i.e., to increase productivity and satisfy societal demands without inflicting environmental harm. GDP growth, education level, life expectancy, health, infant mortality rate, poverty level, labor force participation, urban population, industrialization, and population growth rate are major determinants of socio-economic development (Chien et al., 2022; Yadav et al., 2021). Several of these variables are key predictors of energy consumption, economic growth, and environmental quality (Büchs et al., 2013; I. Khan et al., 2021; Yin et al., 2021; Zhou et al., 2018). However, the COVID-19 epidemic has made it more difficult for the ASEAN area to sustain its growth gains (Yadav & Iqbal, 2021). COVID-19 has significantly impacted various locations, including health, the environment, society, and the economy. It has intensified human suffering, harmed the economy, and endangered countless lives (Mofijur et al., 2021). There are economic, social, and health crises, all of which are indispensable for sustainable growth. The COVID-19 outbreak predominantly impacts the financial sector. As a result of this pandemic, numerous entrepreneurs and businesses have shut down (Fernando et al., 2020). In addition, this pandemic decreased employment in several developing countries. Due to disruptions in global supply systems, epidemic-containment lockdown tactics affect people's mobility. These measures substantially reduce consumption, output, and investment. Tight restrictions on travel and commercial activity imposed by COVID-19 have resulted in an economic slowdown, a decrease in social activities, and an increase in health concerns and energy consumption, which is anticipated to affect energy consumption and environmental damage in the long run (Perdana et al., 2022).

Our study's objective is to assess the impact of socio-economic development, urbanization, and industrialization on the relationship between energy consumption, economic growth, and environmental quality in eight ASEAN countries (Brunei, Malaysia, Indonesia, Myanmar, Singapore, the Philippines, Vietnam, and Thailand) over the period 2000-2020. Socio-economic growth must be studied since, although improving the personal well-being of individuals in ASEAN economies, health, education, and income increase per-capita energy demand and environmental pollution. Following (Azam et al., 2016; Raza et al., 2020; Rej et al., 2018; Sun et al., 2021), socio-economic development is determined using the Human Development Index, urbanization, and industrialization. HDI is the most appropriate instrument for gauging a country's growth and degree of development. It is the geometric mean of all adjusted health, income, and education indices. The health dimension is measured by life expectancy at birth, the educational dimension by mean and average years of schooling, and the living standard is measured by GNI per capita (Yadav et al., 2021). In addition, this study differs from previous research in terms of its empirical estimating methodology. The study used CS-ARDL analysis for the short and long-run estimates, which can address the problem of CSD and slope heterogeneity and yield more reliable results than other panel estimation methodologies.

The primary aims of this research are:

- Examine the influence of HDI, URB, GDP, EC, and IND on CO_2 emissions in ASEAN.
- Examine the impact of HDI, URB, GDP, EC, CO_2, and IND on ASEAN's economic growth.
- Examine the influence of HDI, URB, GDP, GDP, CO_2, and IND on ASEAN's energy consumption.

Due to the academics' general disregard for these areas, there is room to fill this void, allowing future practitioners to learn more about socio-economic development and the energy-growth-environment nexus.

The paper has the following structure: Section 1 addresses the paper's context and purpose. The literature review is offered in section 2, while the research methods, data, and model are discussed in section 3. Section 5 presents results, followed by a summary and policy recommendations in Section 6.

2. Literature Review

Despite many previous studies on the energy-growth-environment nexus, few studies have focused on the ASEAN panel and specific ASEAN nations to examine the energy-growth-environment nexus. Important social and economic aspects that can substantially affect the energy-growth-environment nexus were omitted from these studies, which is a severe restriction. Specifically, (Vo et al., 2019) assessed the relationship between economic growth, carbon emission, energy use, renewable energy consumption, and population using DOLS, FMOLS, and Granger Causality analysis from 1971 to 2014. Their findings revealed no long-term relationship between these variables in Thailand and the Philippines. However, Malaysia, Myanmar, and Indonesia were shown to have a link.

Furthermore, the results of the EKC framework and Granger Causality test varied significantly between member states (Baloch et al., 2022; Chien et al., 2021). Munir et al. (2020) 5 ASEAN nations to examine the causal relationship between GDP, CO2 emissions, and energy consumption throughout 1980-2016 while accounting for CSD. According to the study's findings, unidirectional Granger causation existed between economic growth and CO2 emissions in Malaysia, Thailand, the Philippines, and Singapore; between economic growth and energy usage in Malaysia, Thailand, and Indonesia; and between energy use and development in Singapore. Saboori et al. (2013) also investigated the causative relationship between energy consumption, emissions, and economic growth in the ASEAN-5 economies over the 1971-2009 period using ARDL and Granger Causality analysis of the VECM method. They determined that factors were cointegrated in all five countries and that there was a positive short- and long-term relationship between them. There was a correlation between economic growth and lower CO2 emissions only in Thailand and Singapore.

Safitri et al. (2022) also attempted to estimate the relationship between fossil fuel energy consumption, energy imports, economic growth, electric power consumption, and CO2 emissions. Using ARDL and PMG calculation methods, the study determined that all indicators contributed to CO2 emissions in selected ASEAN nations. In addition to energy consumption and economic growth, (Batool et al., 2021) examined the effect of urbanization on CO2 emission in ASEAN countries using the Granger Causality Model from 1980 to 2018 and discovered that energy consumption and urbanization caused pollution in ASEAN countries (Li et al., 2021; Shah et al., 2021).

Using GMM estimation, (Roespinoedji et al., 2020) investigated the relationship between GDP, CO2 emission, and energy use during the 1975-2016 period while controlling for FDI, industrialization, and population growth. According to the findings, each identified variable positively affected CO2 emission. Using Fixed Effects, Random Effects, and Pooled OLS approaches, (Bieth, 2021) examined the relationship between HDI, GDP, and carbon emission in ASEAN-6 countries and Japan and determined that neither variable had a significant effect on CO2 emission. Using the FMOLS estimating method, Wang et al. (2016) assessed the influence of urbanization on CO2 emission and energy consumption in ASEAN countries, observing a positive effect of urbanization on energy consumption and CO2 emission.

In summary, researchers have explored the growth-energy-environment nexus in the existing literature, but the significance of human development and socio-economic indicators has been comparatively disregarded. In addition, to the best of the Author's knowledge, no previous research in the setting of ASEAN has examined the relationship between socio-economic development, energy consumption, and GDP. Moreover, earlier research that employed CS-ARDL analysis did not consider this nexus's long-run and short-run assessment. This study aims to fill in these gaps in the literature.

3. Estimation Strategy

The foremost goal of this study is to estimate the energy-growth-environment nexus and how this nexus is affected by socio-economic development in ASEAN countries. According to the study objectives, three separate models are framed as follows:

Model 1: CO2 emission model

$$CO_{2it} = \alpha_o + \beta_1 GDP_{it} + \beta_2 EC_{it} + \beta_3 HDI_{it} + \beta_4 URB_{it} + \beta_5 IND_{it} + \quad (1)$$

Model 2: Economic growth model

$$GDP_{it} = \alpha_o + \beta_1 CO_{2it} + \beta_2 EC_{it} + \beta_3 HDI_{it} + \beta_4 URB_{it} + \beta_5 IND_{it} + \quad (2)$$

Model 3: Energy consumption model

$$EC_{it} = \alpha_o + \beta_1 GDP_{it} + \beta_2 CO_{2it} + \beta_3 HDI_{it} + \beta_4 URB_{it} + \beta_5 IND_{it} + \quad (3)$$

Where:

CO2	=	CO2 emission
GDP	=	Economic growth
EC	=	Energy consumption
HDI	=	Human Development Index
IND	=	Industrialization
URB	=	Urbanization

For empirical research, the study utilized a panel dataset for ASEAN countries from 2000 to 2020. The current study focuses on eight ASEAN economies (i.e., Brunei, Malaysia, Indonesia, Myanmar, Singapore, the Philippines, Vietnam, and Thailand). This sample is selected based on the availability of data. The UNDP and World Development Indicators are the sources of data. Urban population is assessed as a percentage of the total population, carbon emissions are calculated as (metric tons per capita), and the annual percentage increase in GDP measures economic growth. Human development is measured using the HDI derived from the UNDP database, while last energy consumption is approximated using energy use (kg of oil equivalent per capita). For analysis, all variables are transformed into logarithmic form.

3.1 CSD and Unit Root Analysis

Our research evaluated the CSD between cross-sections as the initial step before beginning empirical analysis. It is advantageous to utilize specific unit root testing from the first, second, and third generations of tests to combat CSD by testing it prior to unit root testing. CSD is influenced by numerous elements, such as financial and economic integrations, residual dependency, and common shocks, such as oil price shocks, the global financial crisis, globalization, etc. CSD is an issue that cannot be ignored, as it can result in biased results, biased stationarity, size distortion, and biased cointegration outcomes. We apply the CSD test (M. Hashem Pesaran, 2007) to determine whether or not CSD issues are present.

CSD test statistics are as follows:

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right) \sim N(0,1)i,j \quad (a)$$

$$CD = 1, 2, 3, 4 \ldots\ldots\ldots 10 \ldots\ldots\ldots N \quad (b)$$

$$M = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right)\frac{(T-k)\,\hat{\rho}_{ij}^2 - E(T-k)\hat{\rho}_{ij}^2}{Var(T-k)\hat{\rho}_{ij}^2} \quad (c)$$

$\hat{\rho}_{ij}^2$ is the pairwise correlation of residuals. If the panel data in this instance does not demonstrate any CSD, we do not reject the null hypothesis.

After CSD estimation is determined, it is necessary to determine whether or not the panel data is stationary. Numerous academics investigate the non-stationarity issue with panel data. The first, second, and third generation unit root tests are the three basic categories for handling data non-stationarity. These subcategories can be further subdivided based on each method's challenges; however, the 2nd generation unit root test (M. Hashem Pesaran, 2007) addresses heterogeneity and resolves the CSD problem between cross sections. However, the first and second generations lose power and perform poorly if the data contains structural breakdowns.

3rd generation unit root tests accommodate potential structural break heterogeneity in panel data when structural breaks are present. This study uses the approaches of Bai et al. (2009) and M. Hashem Pesaran (2007) to assess the stationarity of the panel data, as the occurrence of CSD renders the use of 1st generation tests incorrect (Jalil, 2014).

3.2 Testing for Cointegration

After determining the stationarity of the series, we estimate the homogeneity or heterogeneity of slope parameters using cointegration, which has been standardized or revised by M Hashem Pesaran et al. (2008). The H0 hypothesis assumes the slope parameters are homogeneous, while the H1 hypothesis suggests they are heterogeneous. Due to size feature distortion, 1st generation cointegration algorithms cannot offer correct estimates because they assume there is no CSD among the cross-sections being evaluated. We apply heterogeneous estimation techniques, such as Westerlund et al. (2008) and Banerjee et al. (2017), where the data contain heterogeneity, non-stationarity, and CSD problems. In addition to addressing the issues mentioned above, the approaches additionally account for structural fractures in the presence of cointegration. While considering heterogeneous slopes parameters and CSD, (Westerlund, 2007) disregards the impact of breaks, which would impede the rejection of the null hypothesis of no cointegration.

In contrast, (Westerlund et al., 2008) considers potential structural breaks for every unit in addition to CSD, heterogeneity, and correlated errors. A similar method (Banerjee et al., 2017) is also used to investigate the cointegration of variables. This method addresses both strong and weak CSD, non-stationary data, and heterogeneity, all of which can be successfully calculated within the framework of false regression.

3.3 CS-ARDL

The global financial crisis and oil prices are just two examples of typical shocks resulting from various sources that may contribute to the CSD problem. This could lead to erroneous findings if unidentified common factors are related to model regressors. When slope heterogeneity and CSD provide a concern, the CS-ARDL can be utilized. The CS-ARDL adopts a dynamic estimate of common correlated effects to circumvent these issues. The preparatory step of CS-ARDL in terms of Eq (f) is as follows:

$$\boldsymbol{W}_{it} = \sum_{l=0}^{p_w} \gamma_{l,i} \boldsymbol{w}_{i,t-l} + \sum_{l=0}^{p_z} \beta_{l,i} \boldsymbol{Z}_{i,t-l} + \varepsilon_{it} \quad \text{(d)}$$

The ARDL model is in equation (d). Results of using eq (e) in the presence of CSD are misleading. To avoid the unsatisfactory conclusion regarding the existence of the threshold effect that CSD generates, eq (e) is an extended form of equation (d) that employs a cross-section average of regressors.

$$\boldsymbol{W}_{it} = \sum_{l=0}^{p_w} \gamma_{l,i} \boldsymbol{w}_{i,t-l} + \sum_{l=0}^{pz} \beta_{l,i} \boldsymbol{Z}_{i,t-l} + \sum_{l=0}^{p_x} \alpha_i' \overline{\boldsymbol{IX}}_{t-l} + \varepsilon_{it} \quad \text{(e)}$$

Where, $\bar{X}_{t-l}$ *is equal to* $\bar{W}_{it-l}$, $\bar{Z}_{it-l}$ Denote averages of dependent and independent variables, pw, px , and pz, which show lags. Moreover, W_{it} denotes the dependent variable, and Z_{it} represents all independent variables. To prevent CSD, X indicates cross-sectional averages. In the CS-ARDL technique, coefficients of the short run are used to calculate long-run coefficients. Below is an illustration of the Mean Group estimation:

$$\hat{\boldsymbol{\pi}}_{CS-ARDL_i} = \frac{\sum_{l=0}^{pz} \hat{\beta}_{li}^{pw}}{1-\sum l=0} \hat{\gamma}_{li} \quad \text{(f)}$$

In eq (f), the mean group is given

$$\hat{\boldsymbol{\pi}}_{MG} = \frac{1}{N} \sum_{i=1}^{N} \hat{\boldsymbol{\pi}}_i \quad \text{(g)}$$

Short run coefficients are as follows:

Error! Bookmark not defined. $\Delta \boldsymbol{W}_{it} = \vartheta_i(\boldsymbol{W}_{it} - \boldsymbol{\pi}_i \boldsymbol{Z}_{it})$ - $\sum_{l=1}^{P_{w-1}} \gamma_{li} \Delta_l \boldsymbol{W}_{it-1} + \sum_{l=0}^{p_z} \beta_{li} \Delta_l \boldsymbol{Z}_{it} + \sum_{l=0}^{px} \alpha_i' \overline{\boldsymbol{IX}}_t + \epsilon_{it}$ (h)

Where ΔI = t-(t-1)

$$\hat{\boldsymbol{\tau}}_i = -(\mathbf{1} - \sum_{l=1}^{pw} \hat{\gamma}_{li}) \quad \text{(i)}$$

$$\hat{\boldsymbol{\pi}}_i = \frac{\sum_{l=0}^{pz} \hat{\beta}_{l,i}}{\hat{\tau}_i} \quad \text{(j)}$$

$$\hat{\boldsymbol{\pi}}_{MG} = \frac{1}{N} \sum_{i=1}^{N} \hat{\boldsymbol{\pi}}_i \quad \text{(k)}$$

ECM displays the speed of equilibrium adjustment.

4. Results and Discussions

Before proceeding to formal analysis, some prerequisite estimation is required, including CDS and unit root testing. CSD analysis findings are given in Table 1, indicating the presence of CSD in data.

Table 1. Results of CSD Test

Series	**t-statistics (prob)**
CO_2	18.422*** (0.000)
GDP	12.341*** (0.000)
EC	19.031*** (0.000)
HDI	20.130*** (0.000)
IND	15.544*** (0.000)
URB	
*** indicate 1 % level of significance. Prob values are enclosed in parentheses.	

In the next step, slope homogeneity is checked by Hashem Pesaran et al. (2008) test. According to table 2, the slope heterogeneity problem exists in our data.

Table 2. Slope Heterogeneity Test

DV: CO_2	
Test- statistics	**Test value/ Prob**
$(\tilde{\Delta})$	45.112*** (0.000)
$(\tilde{\Delta}_{adj})$.	49.255*** (0.000)
*** indicate 1 % level of significance. Prob values are enclosed in parentheses.	

The following step involves stationarity testing of all series as there are CSD and heterogeneous slopes. Bai et al. (2009) and CIPS are used, and Table 3 shows their results.

The table above includes data from country-based analyses that confirm cointegration and a stable relationship among all economies, both with the trend and constant.

We now estimate the association among panel variables after finishing the basic study. CS-ARDL model is used to explore the output coefficients.

Model 1: CO2 Emission Model

CS-ARDL results for Model 1 are shown in Table 6 below.

Table 3. With and Without Structural Break Unit Root Results

	Level			1st difference		
Series	**CIPS**	**MCIPS**			**CIPS**	**MCIPS**
GDP	-3.110***	-5.112**			-	-
CO2	-4.030***	-5.010**			-	-
EC	-4.002***	-3.010**			-	-
HDI	-3.010***	-5.021**			-	-
IND	-4.060***	-5.101**			-	-
URB	-3.010***	-4.111**				
Carrion-i-Silvestre et al. (2009)						
	Z	P_m	P	Z	P_m	P
CO2	0.311	0.456	21.112	-4.040***	3.012***	44.203***
GDP	0.480	0.425	16.010	-4.151***	5.110***	24.033***
EC	0.491	0.324	24.101	-4.102***	4.230***	55.546***
HDI	0.395	0.320	17.106	-3.103***	3.151***	42.834***
IND	0.343	0.405	15.601	-4.145***	5.106***	33.032***
URB	0.445	0.337	14.098	-3.009***	4.009***	23.072***

*** shows 1% significance level.
Bai et al. (2009): CV 2.326, 1.645 and 1.282 for 1, and 5 and 10% level of significance for *Pm* & Z statistics, whereas CV are 56.06, 48.60 and 44.90 for P.

The CIPS and M-CIPS findings suggest that the null hypothesis is rejected, and it is determined that all of the series are level stationery. However, (Bai et al., 2009) findings indicate that sequences contain unit roots at the level. But after taking the first difference, this problem eliminates. Next, (Banerjee et al., 2017) and (Westerlund et al., 2008) cointegration tests allowing structural break are performed. Table 4 provides the results test.

Table 4. Westerlund et al. (2008) Cointegration Test

Test	**No break**	**Mean Shift**	**Regime Shift**
DV: CO2			
$Z_{\varphi}(N)$	-3.030***	-4.011***	-3.021***
$P_{\text{-value}}$	0.000	0.000	0.000
$Z_{\tau}(N)$	-4.041***	-4.040***	-4.050***
$P_{\text{-value}}$	0.000	0.000	0.000

*** indicate 1 % significance level. Prob values are enclosed in parentheses.

The test findings validate the cointegration relationship between CO2, EC, GDP,HDI, URB, and IND at mean regime shift and without a break.In addition, (Banerjee et al., 2017) cointegration test is also conducted, and the results for the full sample confirm long-run cointegration and a consistent relationship with constant and trend, as shown in Table 5 below.

Table 5. Banerjee & Carrion-i-Silvestre Results

Cross sections	**No Deterministic Specification**	**With Constant**	**With Trend**
Dependent Variable: CO2			
Full sample	-3.022***	-4.020**	-5.010**
Brunei	-4.031***	-4.021**	-4.011**
Indonesia	-5.023***	-5.421**	-6.077**
Malaysia	-4.045***	-4.304**	-5.106**
Myanmar	-3.053***	-3.221**	-5.320**
Philippines	-4.051***	-4.051**	-3.014**
Singapore	-6.110***	-5.040**	-4.111**
Thailand	-4.024***	-4.060**	-5.102**
Vietnam	-4.010***	-3.102**	-3.120**

CV (with constant) at 5%** and 10%* is −2.32 and −2.18, whereas CV (with trend) is – 2.82. and −2.92

Table 6. CS-ARDL Analysis

DV: CO2

	Long -Run			Short -Run		
Series	Coefficients	t-statistics	Prob	Coefficients	t-statistics	Prob
GDP	0.536***	4.448	0.050	1.364***	3.138	0.009
EC	1.664***	1.973	0.004	1.440***	4.453	0.080
HDI	-1.574***	-2.112	0.020	-1.032***	-3.120	0.007
IND	0.343**	2.913	0.001	0.271***	3.242	0.030
URB	0.226***	3.554	0.000	0.567***	4.475	0.009
ECT (-1)	-0.332***	-5.140	0.000			
CSD-Statistics	-	-	-		0.098	0.540

** and *** denote 10% and 5% significance level respectively.

According to the statistical results of the CS-ARDL estimation, all of the analyzed independent factors had a substantial impact on CO2 emissions. First, excessive economic growth in ASEAN countries harms the surrounding environment due to high energy consumption and abuse of natural resources. Each percentage point increase in GDP raises CO2 emissions by 0.36 percent and 0.33 percent. Second, EC has a significant and positive effect on CO2 emissions, as CO2 emissions increase by 0.44 percent for every one percent increase in energy consumption. These results accurately reflect the current scenario of the ASEAN nations, which is characterized by higher economic growth fueled by high energy consumption and high environmental pollution. Previous literature (Chontanawat, 2020; Munir et al., 2020; Roespinoedji et al., 2020; Vo et al., 2019) have observed comparable results.

The data suggest that HDI enhances environmental quality by improving human welfare and promoting a sustainable approach. In terms of coefficient, each percent improvement in HDI results in a 0.35 and 0.33 percent decrease in CO2 emissions. Therefore, the primary objective of ASEAN nations must be to promote human development. This study's findings align with those of (Arfanuzzaman, 2016; Mofijur et al., 2021; Sezgin et al., 2021).

URB and IND are positively associated with CO2 emission, as indicated by (Anwar et al., 2020; Brahmasrene et al., 2017; Liu et al., 2018). A one percent rise in urbanization and industrialization is responsible for 0.56 percent and 0.27 percent in the short term and 1.22 percent and 0.34 percent in the long run, respectively. This effect may be attributed to increased traffic, deforestation, increased waste resources, and inefficient waste resource management due to urbanization. Likewise, IND is considerably and positively linked with CO2 emission. IND is associated with greater income and opportunities, increasing energy consumption at the individual and sector levels, and increasing CO2 emissions.

Model 2: Economic Growth Model

The results of Model 2 are presented in Table 7 below.

Table 7. CS-ARDL Findings

DV: GDP

	Long -Run			Short -Run		
Series	**Coefficients**	**t-stat**	**Prob-value**	**Coefficients**	**t-stat**	**Prob -value**
EC	0.836***	3.536	0.004	0.346***	-3.130	0.000
CO2	-0.432*	-1.723	0.084	-0.340***	-4.225	0.004
HDI	0.925***	3.242	0.000	0.017***	4.150	0.000
IND	0.250***	2.011	0.001	0.174***	5.126	0.000
URB	0.818	0.432	0.271	0.987	0.732	0.154
ECT (-1)	-0.214***	-3.140	0.000			
CSD-Statistics	-	-	-		0.053	0.621

*& *** denote 10%, & 1% level of significance respectively.

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Model 3: Energy Consumption Model.

Table 8. CS-ARDL Findings

DV: Energy Consumption

	Long- Run			Short -Run		
Series	Coefficients	t-statistics	Prob-value	Coefficients	t-statistics	Prob -value
CO2	0.816***	2.463	0.000	0.188***	2.110	0.000
GDP	0.426*	2.713	0.042	0.140***	5.115	0.006
URB	0.245***	2.102	0.020	0.116***	4.100	0.000
IND	0.376**	3.241	0.010	0.353***	2.144	0.000
HDI	0.098	0.872	0.112	0.987	0.775	0.430
ECT (-1)	-0.443***	-2.148	0.000			
CSD-Statistics	-	-	-		0.048	0.789

Where, *, ** and *** are 10%, 5% and 1% significance level respectively.

Table 8 provides a summary of model 3's findings. According to the results of (Kahouli et al., 2022; Menyah et al., 2010), CO2 emission has a significant and favorable effect on EC in both the long and medium term (Saidi et al., 2015). Each percent increase in CO2 emissions raises EC by 0.81 percent in the long term and 0.18 percent in the near term. GDP has a large and favorable effect on EC. If GDP increases by 1%, EC will increase by 0.42 percent over the long term and 0.14 percent over the short period. Our findings that economic expansion increases energy consumption are supported by (Farhani et al., 2012; Nasreen et al., 2014; Tang et al., 2016).

IND has been reported to increase EC in ASEAN nations, meaning that higher-value manufacturing consumes more energy than traditional industrial or agricultural operations. In terms of coefficients, a 1% increase in industrialization increases energy consumption by 0.35 % in the short time and 0.37 % in the long term for each additional unit of automation. Earlier investigations (Kahouli et al., 2022; Sadorsky, 2014; Sahoo et al., 2020) also found identical outcomes. Moreover, according to (Belloumi et al., 2016; Sheng et al., 2017; Wang et al., 2016), URB has a substantial favorable effect on energy usage. Each percentage point increase in URB causes an increase in EC of 0.11% in the short run and 0.24% in the long run. This impact can be understood in the following manner: Given that urbanization involves the movement of agricultural labor to the industrial and service sectors in urban districts during industrialization, there is a strong relationship between urbanization and economic growth. Urbanization increases energy demand because energy consumption is positively related to financial expansion (Begum et al., 2015). In the long and near term, HDI has been found to have no appreciable effect on energy usage.

5. Summary and Policy Recommendations

The primary purpose of this study is to estimate the socio-economic development (as defined by HDI) of the energy-growth-environment nexus in ASEAN-8 economies for the period 2000-2020. To the Author's knowledge, no prior research has examined this relationship by considering the socio-economic development of ASEAN nations. After confirming CSD and slope heterogeneity in the data, the second-generation estimation method of CS-ARDL is used to estimate the balanced panel data of eight ASEAN countries. The evaluation includes the CO2 emission model, the economic growth model, and the energy usage model. According to the study's findings, HDI, EC, GDP, URB, and IND all have substantial negative or positive effects on CO2 emission. The HDI harms CO2 emission, while all other variables have a positive impact. CO2 has a detrimental effect on economic growth, while all other variables have a favorable outcome. However, URB has little impact on development. HDI has no significant effect on energy consumption in the energy consumption model, but all other factors have a positive impact.

As a result of these findings, there are several worthy policies for ASEAN practitioners and policymakers. Recognizing the importance of human development as a significant contributor to economic growth and the improvement of a country's environmental quality, it is recommended that well-designed policies be efficiently executed to accelerate the rate of human development. The planning and implementation phases of programs meant to increase health and education in emerging economies are manifestly deficient. One of the keys to achieving a higher degree of human development and, by extension, higher levels of economic growth and environmental quality is to boost funding for education and health. Additionally, more energy-saving measures must be developed to reduce CO2 emissions. The examined nations must promote green and sustainable urbanization to advance and sustain economic progress without destroying the environment. Governments should also encourage using renewable energy sources in urban areas, such as solar lighting, heating systems, and ethane-fueled autos, to optimize the energy consumption structure and maximize the effect of renewable energy on future urbanization. These economies must alter their industries administratively while promoting low- and zero-emission initiatives and industrial diversity. Moreover, businesses and individuals should promote recycling and decrease energy waste to increase their environmental consciousness.

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