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-RESEARCH ARTICLE-

DOES URBANIZATION, INDUSTRIALIZATION, AND INCOME UNEQUAL DISTRIBUTION LEAD TO ENVIRONMENTAL DEGRADATION? FRESH EVIDENCE FROM ASEAN

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─Abstract─

Over recent years, the income gap within the Association of Southeast Asian Nations (ASEAN) has widened, while the rate of environmental degradation has drastically accelerated since the 1990s. In past literature from diverse disciples, the threat to environmental sustainability posed by industrialization and urbanization has been studied by scholars and researchers. The key objective of the present study is to investigate into whether factors like industrialization, urbanization, income inequality, real per capita output and human capital index play a role in ensuring environmental sustainability in terms of carbon emission in three different measures. Data is collected through the World Bank website for the period of 1995-2015, and panel regression methods have been applied due to the time series and cross-sectional nature of the units of observations. Study results confirm that industrialization is a direct cause of environmental sustainability issues as reflected in the high levels of CO2 emissions from transport (% of total fuel combustion). At the same time, urbanization and human capital index are causing a decline in the levels of carbon emission. Additionally, this study provides a valuable empirical framework for exploring the relationship between the understudy variables. However, various limitations should also be noted while reviewing and using the results of the present study. The present study only targets six economies out of the whole ASEAN region, applies traditional panel regression models, is notably missing some descriptive details of the data and study variables, and applies some robust checks as well. This means that future studies should be encouraged to cover the gap by addressing and overcoming these limitations in the future. Lastly, this study highlights some practical implications specifically in the context of ASEAN economies.

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Vol: 13 **No:** 1 **Year:** 2021 **ISSN**: 1309-8055 (Online) (**pp.** 253-272) **Doi:** 10.34109/ijefs.20212012

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JEL Classifications: Q56, O44, O14

1. INTRODUCTION

Due to an increase in economic activity, there is a growing concern regarding the quality of the natural environment (Chen et al., 2019). It is believed that due to this increased threat to the natural environment, there is a prominent existential risk faced by human and nonhuman populations around the world (Zafar et al., 2019). Furthermore, environmental concerns include concerns relating to the threat to ecological and various other natural resources (Amen et al., 2021; Kamran et al., 2020). In the context of the global economy, where there is a high level of competition among firms and economies, there is much more unrest experienced in the developing economies in terms of inequalities and impact on the environment (Hao et al., 2021a). Furthermore, an acute level of income inequality can lead to the careless use of resources by the the priviliged sections of the society. It is important to note that more specifically, higher inequality provides an easy way for a certain group in any economy to occupy an advantageous position (Masud et al., 2018). However, such a position may lead to the mis-utilization of various resources, causing more unrest in the community. Another view in the existing body of literature is that higher income inequality in any economy can negatively affect the environmental variables in the form of waste generation, biodiversity loss as well as water consumption (Uzar, 2020). A piece of significant evidence is observed which claims that the outcome of low sustainability level can hurt the poor communities and nations more than the affluent ones (Demir et al., 2019).

Moreover, another well-established notion is that the concept of industrial growth is linked with the environment in the sense that it affects the environment in severe and negative ways (Sharma et al., 2021). The reason is that it causes tremendous stress on the entire network and natural system in various ways. For example, increasing industrial growth affects the stablility of natural systems (Arrigoni et al., 2017) like water, air, soil, biodiversity, as well as natural ecosystems at large. To mitigate the adverse impact of industrialization on the natural environment, various approaches like green efforts, which covers the use of 6Rs technologies, are also under consideration (Liu et al., 2018). Such efforts can not only protect the natural environment but also provide practical options to promote and ensure sustainable development.

The start of the 21st century marked a historical transition in terms of the urbanization as half of the world population now resides in urban regions or centres (Muhammad et al., 2021). This dramatic change has created much pressure, both, on individual lives as well as on the natural environment. Meanwhile, earlier researchers have also focused on the implications and origin of urbanization while focusing more on its technological development in different economies. This study aims to investigate the trends in environmental sustainability as measured through urbanization, industrialization,

Vol: 13 **No:** 1 **Year:** 2021 **ISSN**: 1309-8055 (Online) (**pp.** 253-272) **Doi:** 10.34109/ijefs.20212012

income inequality, real per capita oncome, and human capital as well. This study is a valuable addition to the existing literature on the subject as it covers specific factors which, with some administration, can be useful in controling the scale of encironmental degradation by reducing CO2 emsision, nitrous oxide emission, and greenhouse gas emissions. While a number of past research studies have highlighted factors and solutions vis-à-vis environmental degradation, our study analyses some of the factors as causes and other factors as measures to control environemnatal degradation for the same time period. This study analyzes the economies of ASEAN after collecting data regarding urbanization, industrialization, income inequality, real per capita oncome, and human capital as well as their impact on CO2 emsision, nitrous oxide emission, and greenhouse gas emissions.

The rest of the paper is organized as follows. Section two reviews existing literature on the subject, and section three provides the study methods and related details. Section four discusses the key variables and their definitions along with how they are measured in quantifiable terms. Section five highlights and discusses the study results, and the last section concludes the study by identifying its implications as well as directions for future research.

2. LITERATURE REVIEW

Numerous studies in the past explore the trends in sustainable environment as a result of urbanization and industrialization. For example, Patnaik (2018) explains how industrialization has brought significant economic prosperity but has also been marked by increased stress on the supporting system as well as adverse environmental effects. Furthermore, he states that accumulating evidence has shown that through the implementation of successful green approaches, a viable solution to preserve the natural environment is possible. Additionally, causal chain analysis reflects that severe impacts of industrialization on the local environment are observable. Adebayo and Kirikkaleli (2021) claim that East Asian economies are growing at a faster rate. However, this increasing trend has also created some environmental stresses in the form of air pollution, water shortages, marine pollution, deforestation etc. He further shows that the environmental sustainability index or ESI reported by the World Economic Forum during 2005 is a good indicator to help analyze key trends in the natural environment. Besides, the author has discussed the environmental impact of industrialization theoretically while claiming that significant attention is required to protect the natural environment from the increasing threat of urbanization.

Effiong (2018) focuses on the urbanization-pollution nexus in Africa through a semiparametric analysis. Their study considers 49 African countries during the time period from 1990 to 2010 while applying stochastic impacts by regression on the pollution. Furthermore, through a semi-parametric panel fixed effect regression approach, their study has estimated the relationship between air pollutants like carbon

Vol: 13 **No:** 1 **Year:** 2021 **ISSN**: 1309-8055 (Online) (**pp.** 253-272) **Doi:** 10.34109/ijefs.20212012

dioxide emission and ambient particulate matter emissions along with urbanization. It is observed that urbanization reduces environmental pollution in the targeted economies. However, there is no evidence for the presence of Kuznets hypothesis of an inverted U-shaped curve between urbanization and environmental pollution. Azam et al. (2016) have empirically tested the impact of urbanization along with some explanatory variables on environmental degradation while considering the carbon dioxide emission for India, Pakistan, Sri Lanka and Bangladesh. Annual data was collected for the time period from 1982-2013 with yearly observations. The least-square method of analysis reveals that the impact of urbanization on the environment is blended. In case of India and Bangladesh, the association between urbanization growth and environment is found to be negatively significant. Whereas for the other two countries is found to be significant and positive.

Liang et al. (2019) have also analyzed the linkage between urbanization and environmental pollution in the economy of China. They further claim that the impacts of urbanization on environmental pollution fluctuated over a period of time. However, various policies have been used to promote the coordination between the dyanmics of urban development and environmental protection. Besides, urban development paths should be set according to topography. Li et al. (2019) also focus on the impact of urbanization and industrialization on energy security for the region of China. They have claimed that it has become evident that there is work for sustainable energy development based on energy security, energy affordability, and environmental sustainability. They further claim that an increase in the value of energy efficiency tends to lead towards both, environmental sustainability and energy security. Masud et al. (2018) argues that the income gap among the ASEAN economies has been high since the 1990s, and the same is found to be true for environmental degradation. Using the Gini coefficient as a core measure of income inequality, their paper has examined the association between income inequality and environmental sustainability. They have collected the data from 1985-2015 while applying Granger causality and panel regression as well. Hao et al. (2021b) have studied the nexus between green growth, low carbon emission, renewable energy and human capital among G7 economies. They have claimed, on the basis of empirical evidence, that the association between the stated variable is missing specifically in G7 member states. Therefore, they have conducted an empirical investigation for the study variables while considering the human capital, green growth and environmental tax as the main explanatory variables. It is claimed that through all the explanatory variables, there is a decline in carbon emissions where the role of renewable energy is also observed as a negative determinant of carbon emission.

Sarkodie (2018) analyzes the key drivers of environmental degradation in 17 African countries from 1971 to 2013. The Westerlund error-correction model and panel cointegration tests with one thousand bootstrapping samples, U-shape estimator, fixed and random effect tests, and panel causality test were used to examine the empirical study. The empirical results show that real per capita output which indicates economic

Vol: 13 **No:** 1 **Year:** 2021 **ISSN**: 1309-8055 (Online) (**pp.** 253-272) **Doi:** 10.34109/ijefs.20212012

growth and the resultant energy consumption, agriculture, food production, permanent crop, and fertility rates has an important impact on environmental deterioration in Africa, and hence can assist global indicators for reaching the 2030 Sustainable Development Goals. A research was conducted by Alvarado et al. (2018), to examine the association between real per capita output and CO2 emissions, globally in general and ASEAN countries in particular. Panel data for the period of 1980-2016 from 151 countries is selected as per the income level applying the World Bank Atlas Method. The classification was made because of the argument that the potential of the relation between the two factors differs according to the income level of nations. Based on the Kuznets environmental curve's theoretical framework, there is a substantial U-shaped association between the real per capita output and CO2 emission in middle-high and low-income nations. In high- middle-high-income economies, the Kuznets environmental curve hypothesis holds valid.

The above discussion has clearly shown that urbanization, industrialization, human capital index and income inequality can be used or identified as core determinants of environmental sustainability specifically in the ASEAN region. Furthermore, when determining the outcome of environmental substantiality, per capita output cannot be ignored. However, in the context of the ASEAN economies, little has been investigated in this regard. Therefore, the present study seeks to fill the both in theoretical as well as empirical literature on the subject. For this reason, the contribution provided by current study carries major theoretical and empirical implications.

3. METHODOLOGY

This research uses historical data from the World Bank database during the time duration of 1995-2015 with respect to all the variables understudy. Out of all the ASEAN economies, six countries have been selected, named Malaysia, Indonesia, Thailand, Philippines, Singapore, and Laos. Due to the time series and cross-sectional nature of the units of observation, the data for the present study is deemed panel data in nature which has different subcategories, like balanced panel or unbalanced panel. As all units of observations are considered for all the time series, therefore, the data under the present study is found to be strongly balanced. Based on the panel regression models, we have focused on the general regression equation, which covers the association between dependent and independent variables of the study.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k + e_{it} \quad \textbf{(1)}$$

In equation (1), ŷ is the predicted value of the dependent variable of the study during a period of time. Values of the k independent variables or key repressors in the equation are denoted by X_1, X_2 and X_k. Finally, we have the b's that are constants, called regression coefficients. Values are assigned to the b's based on the principle of least squares as well. Thus, using current study variables, the equations of the study are as follow:

Vol: 13 **No:** 1 **Year:** 2021 **ISSN**: 1309-8055 (Online) (**pp.** 253-272) **Doi:** 10.34109/ijefs.20212012

$$CO2T = \beta_0 + INDUS_1X_1 + \beta_2URBAN_2 + \beta_3INEQ_3 + \beta_4RPC_4 + \beta_5HCI_5 + \acute{\varepsilon} \quad \textbf{(2)}$$

$$NOE = \beta_0 + INDUS_1X_1 + \beta_2URBAN_2 + \beta_3INEQ_3 + \beta_4RPC_4 + \beta_5HCI_5 + \acute{\varepsilon} \quad \textbf{(3)}$$

$$LOGGGE = \beta_0 + INDUS_1X_1 + \beta_2URBAN_2 + \beta_3INEQ_3 + \beta_4RPC_4 + \beta_5HCI_5 + \acute{\varepsilon} \quad \textbf{(4)}$$

The first equation (above) has been further extended to the fixed effect estimator, which specifies that there is heterogeneity among the selected entities or states which can affect the relationship between predictors and outcome variables of the study. This is among one of the core characteristics of the fixed effect, which controls/fixes the difference among the entities so that the coefficients can represent the true effect of the explanatory variable on the key dependent variables of the study. The following Equation 5 shows the fixed effect regression model as considered under the present study.

$$Y_{it} = \beta_{1i} + \beta_2X_{2it} + \beta_3X_{3it} + \beta_4X_{4it} + \beta_5X_{5it} + u_{it} \quad \textbf{(5)}$$

Where in above Equation 2, the terms reflect the time duration of the study, and *i* refers to the units of observations under consideration. Here, in our example, the time duration is between 1995-2015, and a total of six entities from all ASEAN economies are under consideration. We aim to estimate β1 the effect on Yi of a change in Xi holding constant $Z_{i.}$ Thus, using current study variables, the equations of FEM are as follow:

$$CO2T_{it} = \beta_{1i} + \beta_2INDUS_{2it} + \beta_3URBAN_{3it} + \beta_4INEQ_{4it} + \beta_5RPC_{5it} + \beta_6HCI_{6it} + u_{it} \quad \textbf{(6)}$$

$$NOE_{it} = \beta_{1i} + \beta_2INDUS_{2it} + \beta_3URBAN_{3it} + \beta_4INEQ_{4it} + \beta_5RPC_{5it} + \beta_6HCI_{6it} + u_{it} \quad \textbf{(7)}$$

$$LOGGGE_{it} = \beta_{1i} + \beta_2INDUS_{2it} + \beta_3URBAN_{3it} + \beta_4INEQ_{4it} + \beta_5RPC_{5it} + \beta_6HCI_{6it} + u_{it} \quad \textbf{(8)}$$

After analyzing the fixed effect regression estimation, we have developed the following random effect model.

$$Y_{it} = \beta_1 + \beta_2X_{2it} + \beta_3X_{3it} + \beta_4X_{4it} + \beta_5X_{5it} + \mathcal{E}_i + u_{it} \quad \textbf{(9)}$$

$$Y_{it} = \beta_1 + \beta_2X_{2it} + \beta_3X_{3it} + \beta_4X_{4it} + \beta_5X_{5it} + w_{it} \quad \textbf{(10)}$$

In the equation above, $w_{it} = \varepsilon_i + \mu_{it}$ and ε_i shows the "individual error component" while μ_{it} shows the "time-series error" and combined "cross-section component". Thus, using current study variables, the equations of REM are as follow:

$$CO2T_{it} = \beta_1 + \beta_2INDUS_{2it} + \beta_3URBAN_{3it} + \beta_4INEQ_{4it} + \beta_5RPC_{5it} + \beta_6HCI_{6it} + w_{it} \quad \textbf{(11)}$$

Vol: 13 **No:** 1 **Year:** 2021 **ISSN**: 1309-8055 (Online) (**pp.** 253-272) **Doi:** 10.34109/ijefs.20212012

$$NOE_{it} = \beta_1 + \beta_2 INDUS_{2it} + \beta_3 URBAN_{3it} + \beta_4 INEQ_{4it} + \beta_5 RPC_{5it} + \beta_6 HCI_{6it} + w_{it} \quad \textbf{(12)}$$

$$LOGGGE_{it} = \beta_1 + \beta_2 INDUS_{2it} + \beta_3 URBAN_{3it} + \beta_4 INEQ_{4it} + \beta_5 RPC_{5it} + \beta_6 HCI_{6it} + w_{it} \quad \textbf{(13)}$$

After discussing the general panel regression equations, all of the above were turned into more specific formulae where the details for the key dependent and independent variables are provided under the results and discussion section of the study.

4. RESULTS

The correlation matrix is provided under Table 2 of the study, along with the level of significance against each of the coefficients of correlation. The findings show that the correlation between carbon emission from transport and nitrous oxide emissions (% change from 1990) is negatively significant at 1 per cent with the correlation coefficient of -0.893. At the same time, the correlation between carbon emission from transport and Total greenhouse gas emissions (kt of CO2 equivalent) in terms of log values are positively significant at 1 per cent. This indicates a good interdependency among each other. The rest of the variables are found to be insignificantly correlated with the CO2T except human capital index, which shows a weak, negative and significant correlation (r=-0.184, p-value= 0.000). The third column under Table 2 shows the correlation between the NOE and the rest of the variables of the study. The results confirm that there is a positive and significant association between NOE and LOGGGE at 1 per cent (r= 0.715, p-value=0.000). However, no significant correlation of NOE is found among all other variables. Similarly, the correlation coefficient between LOGGGE and all other variables of the study has provided evidence for insignificant association, and the same case is for the INUDS. Furthermore, a weak positive and significant correlation between urbanization and income inequality is found (r=0.202, p-value=0.000), but the rest of the variables are insignificantly related to URBAN. Meanwhile, there is a negative and weak correlation between INEQ and HCI (r= -0.183, p-value= 0.000).

After examining the trends in correlation, it is found that there is no higher association among the study variables; Table 3 provides the values for the individual variance inflation factor or VIF as well as overall, that is, through the mean score. It is observed that the VIF for RPC, URBAN, INEQ, HCI, INDUS is relatively lower than five, which is accepted as a threshold point. Similarly, the value of Mean VIF is also lower than five, which means both individual, as well as mean VIF, have provided the evidence for no higher correlation or issue of multicollinearity among the study variables.

Vol: 13 **No:** 1 **Year:** 2021 **ISSN**: 1309-8055 (Online) (**pp.** 1-24) **Doi:** 10.34109/ijefs.202112222

Table 1. Description of the Variables

Name and Abbreviation	Description of the Variable	Measurement of the Variable
CO2T; Carbon emissions from transport	"It shows the total carbon dioxide emissions from transport as a percentage of total fuel combustion."	% of total fuel combustion
NOE; Nitrous oxide emissions	"Nitrous oxide is emitted from wastewater that contains nitrogen-based organic materials, such as those found in human or animal waste."	% change from 1990
LOGGGE; the log of Total greenhouse gas emissions.	"Total greenhouse gas emissions are the sum of emissions of various gases: carbon dioxide, methane, nitrous oxide, and smaller trace gases."	kt of CO2 equivalent
INDUS; Industrialization,	"Industrialization includes value added in mining, manufacturing, construction, electricity, water, and gas."	"The proportion of value added by secondary industry in GDP."
URBAN; urbanization,	"Urbanization refers to people living in urban areas."	"Urban population as a share of the total population."
INEQ; income inequality,	"Unequal distribution of income among the various local community members."	"Gini coefficient (for overall and bottom 40%) as a measure of income Inequality."
RPC; Real per capita output,	"Measurement of the total economic output of a country divided by the number of people and adjusted for inflation."	"Measurement of the total economic output of a country divided by the number of people and adjusted for inflation."
HCI; Human capital index	"The index measures the amount of human capital that a child born today can expect to attain by age 18, given the risks of poor health and poor education that prevail in the country where she lives."	"Based on the core measurement as provided by the World Development Indicators."

Vol: 13 **No:** 1 **Year:** 2021 **ISSN**: 1309-8055 (Online) (**pp.** 253-272) **Doi:** 10.34109/ijefs.20212012

Table 2. Pairwise Correlations

Variables	**CO2T**	**NOE**	**LOGGGE**	**INDUS**	**URBAN**	**INEQ**	RPC	HCI
CO2T	1.000							
NOE	-0.893*	1.000						
	(0.000)							
LOGGGE	0.770*	0.715*	1.000					
	(0.000)	(0.000)						
INDUS	-0.037	0.048	0.009	1.000				
	(0.686)	(0.609)	(0.921)					
URBAN	-0.024	-0.004	-0.005	-0.160	1.000			
	(0.795)	(0.966)	(0.957)	(0.081)				
INEQ	-0.078	0.044	0.156	-0.069	0.202*	1.000		
	(0.395)	(0.638)	(0.089)	(0.452)	(0.027)			
RPC	0.006	0.059	-0.073	-0.020	-0.126	0.032	1.000	
	(0.952)	(0.524)	(0.429)	(0.829)	(0.171)	(0.725)		
HCI	-0.184*	0.153	0.086	0.107	-0.064	-0.183*	-0.021	1.000
	(0.044)	(0.098)	(0.350)	(0.246)	(0.488)	(0.045)	(0.821)	

*CO2T; Carbon emissions from transport (% of total fuel combustion), NOE; Nitrous oxide emissions (% change from 1990), LOGGGE; log of Total greenhouse gas emissions (kt of CO2 equivalent), INDUS; Industrialization, URBAN; urbanization, INEQ; income inequality, RPC; Real per capita output, HCI; Human capital index, *** p<0.01, ** p<0.05, * p<0.1*

Vol: 13 **No:** 1 **Year:** 2021 **ISSN**: 1309-8055 (Online) (**pp.** 1-24) **Doi:** 10.34109/ijefs.202112222

Table 3. Variance Inflation Factor

	VIF	**1/VIF**
RPC	1.156	.865
URBAN	1.065	.939
INEQ	1.06	.943
HCI	1.058	.945
INDUS	1.039	.962
MEAN VIF	1.076	.

INDUS; Industrialization, URBAN; urbanization, INEQ; income inequality, RPC; Real per capita output, HCI; Human capital index, VIF; variance inflation factor

Regression results are provided in Table 4, where the first dependent variable is CO2 emissions from transport (% of total fuel combustion). The study results confirm a positive impact from industrialization on environmental sustainability as measured through carbon emission from transport. This effect is justified through regression in all three-regression models where the relative coefficients are 1.557, 0.986, and 1.557, respectively. It means that industrialization is causing more carbon emissions in the natural environment of all six ASEAN economies. However, the impact from urbanization on carbon emission from transport is entirely different which is negatively significant at 1 per cent (see Model 1, coefficient= 1.010, standard error= 0.385, p-value= 0.000). This effect is not significant under fixed effect results where the coefficient of URBAN is positively insignificant. On the other side, the random effect model reflects that there is an adverse effect of urbanization on carbon emission with the coefficient of -1.010, which is significant at 1 per cent. For income inequality, ,none of the models has provided any statistical evidence for the significant impact on the environmental sustainability as measured through CO2 emissions from transport (% of total fuel combustion). The impact from real per capita output or RPC on CO2 emissions from transport (% of total fuel combustion) is positively significant at 1 per cent in Model 1. However, under Model 2 and 3, no significant impact is observed. Lastly, the impact of the human capital index on carbon emission is negatively significant in all three-panel models. It means that higher HCI means lower carbon emission and vice versa.

The relationship between industrialization, urbanization, income inequality, real per capita output, human capital index and second measurement of environmental sustainability is observed under Table 5. Findings through multiple regression and fixed-effect model specify a highly significant and direct impact of industrialization on NOE; Nitrous oxide emissions (% change from 1990) through the coefficient of 2.849 and 3.445, respectively. It means that more industrialization means more NOE; Nitrous oxide emissions (% change from 1990) in all panel economies of the ASEAN region. However, the impact of urbanization on nitrous oxide emissions is insignificant.

Vol: 13 **No:** 1 **Year:** 2021 **ISSN**: 1309-8055 (Online) (**pp.** 253-272) **Doi:** 10.34109/ijefs.20212012

Table 4. Impact of Industrialization, Urbanization, Income Inequality, Real Per Capita and HCI on CO2T; Carbon Emissions From Transport (% of Total Fuel Combustion)

	OLS	**FEM**	**REM**
VARIABLES	**Model 1**	**Model 2**	**Model 3**
INDUS	1.557***	0.986***	1.557***
	(0.496)	(.057)	(.014)
URBAN	-1.010***	0.112	-1.010***
	(.385)	(.921)	(.358)
INEQ	-7.153	-8.212	-7.153
	(5.959)	(7.125)	(5.958)
RPC	1.123***	-0.0541	0.123
	(.186)	(6.172)	(5.324)
HCI	-11.85**	-13.30**	-11.85***
	(5.451)	(5.213)	(4.400)
Constant	22.36***	22.74**	22.36***
	(6.450)	(8.288)	(7.202)
Observations	120	120	120
R-squared	0.348	0.258	0.327
Number of years	20	20	20

*CO2T; CO2 emissions from transport (% of total fuel combustion), INDUS; Industrialization, URBAN; urbanization, INEQ; income inequality, RPC; Real per capita output, HCI; Human capital index, *** p<0.01, ** p<0.05, * p<0.1, Standard errors in parentheses,*

Finally, the impact from the human capital index on the second environmental factor is found to be positive and significant in all three-panel models, where the highest impact is observed through random effect regions which shows a coefficient of 14.55 with the standard error of 6.725, respectively. It means that the HCI index is positively linked with environmental sustainability in the region of ASEAN economies. As per the explained variation, Model 1 shows the value of R2 as 13.4 per cent, while Model 2 indicates the values of R2 as 24.5 per cent, and Model 3 specifies it as 12.8 per cent, accordingly. All these models have also indicated that they are statistically fit due to some reasonable value of the R2 under each of the panel regression predictions.

Finally, Table 6 given below provides the panel outcomes while considering the title of LOGGGE; log of Total greenhouse gas emissions (kt of CO2 equivalent) as the main dependent variable of the study. The stated findings justify the argument that higher industrialization and related activities are causing higher greenhouse gas emissions in the ASEAN economies. This impact is justified through Model 1, which is used for the multiple regression and Model 3, which specifies the random effect.

Vol: 13 **No:** 1 **Year:** 2021 **ISSN**: 1309-8055 (Online) (**pp.** 253-272) **Doi:** 10.34109/ijefs.20212012

Table 5. Impact of Industrialization, Urbanization, Income Inequality, Real Per Capita and HCI on NOE; Nitrous Oxide Emissions (% Change from 1990)

	OLS	**FEM**	**REM**
VARIABLES	**Model 1**	**Model 2**	**Model 3**
INDUS	2.849***	3.445***	2.849
	(0.107)	(0.101)	(9.199)
URBAN	0.638	-0.0790	0.638
	(6.842)	(8.297)	(7.134)
INEQ	5.947	6.247	5.947
	(7.570)	(9.702)	(8.368)
RPC	4.361	6.178	4.361
	(6.552)	(6.183)	(5.580)
HCI	12.08*	14.55**	12.08**
	(6.920)	(6.725)	(6.063)
Constant	17.18**	14.84*	17.18**
	(8.315)	(8.106)	(7.312)
Observations	118	118	118
R-squared	0.134	0.245	0.128
Number of years	20	20	20

*NOE; Nitrous oxide emissions (% change from 1990), INDUS; Industrialization, URBAN; urbanization, INEQ; income inequality, RPC; Real per capita output, HCI; Human capital index, *** p<0.01, ** p<0.05, * p<0.1, Standard errors in parentheses,*

It means that out of three-panel models, two have proved the direct impact of industrialization on greenhouse emissions during the last 20 years. However, the impact from urbanization is found to be negatively insignificant under all three-panel models. Additionally, the impact of income inequality on all total greenhouse gas emissions are also directly significant at 5 per cent in multiple regression and10 per cent both in fixed and random effect. This would mean that higher income inequality among the ASEAN states is causing higher greenhouse gas emissions which points to a serious concern. However, the impact from real per capita output and human capital index is not statistically significant, which means that there is no impact of both of these independent variables on the total greenhouse gas emission.

5. DISCUSSIONS

The study results have indicated that industrialization has a positive impact on CO2 emissions. These results are supported by the previous study of Nasir et al. (2021), which analyses the influences of industrialization on environmental quality. The study highlights that ever since the industrialization of countries, the amount of CO2 emission

Vol: 13 **No:** 1 **Year:** 2021 **ISSN**: 1309-8055 (Online) (**pp.** 253-272) **Doi:** 10.34109/ijefs.20212012

has been increasing fast because of the increased use of energy resources, technologies, plants, and transportation.

Table 6. Impact of Industrialization, Urbanization, Income Inequality, Real Per Capita and HCI on LOGGGE; the Log of Total Greenhouse Gas Emissions (kt of CO2 Equivalent)

	OLS	FEM	REM
VARIABLES	**Model 1**	**Model 2**	**Model 3**
INDUS	0.858***	-0.0429	0.6358***
	(0.0868)	(0.116)	(0.011)
URBAN	-0.0410	-0.0925	-0.0410
	(0.0850)	(0.125)	(0.120)
INEQ	0.187**	0.243*	0.187*
	(0.0941)	(0.127)	(0.106)
RPC	-0.0730	-0.0794	-0.0730
	(0.0819)	(0.0964)	(0.0852)
HCI	0.107	0.128*	0.107*
	(0.0861)	(0.0686)	(0.0646)
Constant	5.501***	5.509***	5.501***
	(0.102)	(0.116)	(0.108)
Observations	120	120	120
R-squared	0.246	0.163	0.183
Number of years	20	20	20

*LOGGGE; the log of Total greenhouse gas emissions (kt of CO2 equivalent), INDUS; Industrialization, URBAN; urbanization, INEQ; income inequality, RPC; Real per capita output, HCI; Human capital index, *** p<0.01, ** p<0.05, * p<0.1, Standard errors in parentheses,*

Resultantly, the increased amount of carbon emission destroys the air quality, spoils the natural resources, and causes global warming. These results are also in line with the previous study of Destek et al. (2019), which suggests that in countries where there are a large number of industries that apply different technologies and technical processes based on energy and chemical usage, there is a large amount of CO2 emission into the air. The results of the study have also indicated that urbanization has a negative impact on CO2 emission. These results are supported by the previous study of Adebayo, Agboola, et al. (2021), which shows that urbanization creates awareness among people about environmental issues and needs as well as ways to maintain the level of CO2 emissions released into the air. The study results have indicated that income inequality has a positive impact on CO2 emission. These results are supported by the previous study of M. A. Baloch et al. (2020), which states that in a country where there is inequality in the distribution of income, there are more chances of using a large amount of energy

Vol: 13 **No:** 1 **Year:** 2021 **ISSN**: 1309-8055 (Online) (**pp.** 253-272) **Doi:** 10.34109/ijefs.20212012

resources (which are the largest source of CO2) but low precautions to control CO2 emission. The study results have revealed that real per capita income has a positive impact on CO2 emission. These results are in line with the previous study of Bello et al. (2018), which shows that the increase in the real per capita income corresponds to an increase in economic growth and national earnings, which requires large productivity and transportation infrastructure, causing an increase in the amount of CO2 emission. The study results have indicated that the human capital index has a negative impact on CO2 emission. These results agree with the previous study of Özokcu et al. (2017), which posits that in order to tackle environmental issues, like CO2 emission levels, which are considered the prominent indicators of environmental degradation, not only energy-efficient technologies, ecological resources, and effective processes but also the skilled human resources which are required to reduce CO2 levels in the atmosphere.

The study results have indicated that industrialization has a positive impact on nitrous oxide emission. These results are supported by the previous study of Hafeez et al. (2018), which highlights that the major sources of nitrous oxide emission are the combustion of fossil fuels, biomass burning, and harmful wastes, which are all linked with industries. The study results have indicated that urbanization has a positive impact on nitrous oxide emissions. These results are supported by the previous study of Gasimli et al. (2019), which shows that urbanization develops awareness in public to reduce the chances of nitrous oxide emission in order to ensure environmental protection and create manners in them as to how to get rid of the harmful wastes of any living being which remains the largest source of nitrous oxide emission. The study results have indicated that inequality of income has a positive impact on nitrous oxide emission. These results are in line with the previous study of A. Baloch et al. (2018), according to which, in a situation when there is inequal distribution of income within the country, a portion may not have the awareness and abilitity to control but may become a cause of large amounts of nitrous oxide emissions released in the air. The study results have indicated that real per capita income has a positive impact on nitrous oxide emission. These results are supported by the previous study of Belaid et al. (2017), which highlights that a high real per capita income causes a large amount of nitrous oxide emission. The study results have revealed that human capital has a negative impact on nitrous oxide emission. These results are in line with the study of Hassan et al. (2015), which shows that for efficient policy-making and designing of strategies to protect the environment from nitrous oxide emission, skilled human resources are required.

The study results have shown that industrialization has a positive impact on greenhouse gas emissions. These results are in line with the previous study of Nasrollahi et al. (2020), which shows that an increase in industrial activities causes environmental degradation due to the use of energy resources like buring fossil fuels, electricity, heat, and transportation release greenhouse gas. The study results have revealed that urbanization has a negative impact on greenhouse gas emissions. These results are in line with the previous study of Nathaniel et al. (2021), which also examines a negative

Vol: 13 **No:** 1 **Year:** 2021 **ISSN**: 1309-8055 (Online) (**pp.** 253-272) **Doi:** 10.34109/ijefs.20212012

impact of Urbanization on the greenhouse gas emissions and environmental degradation. The study results have further demonstrated that income inequality has a positive impact on greenhouse gas emissions. These results are in line with the previous study of Uzar et al. (2019), which examines that when a country faces income inequality, a set of population uses natural resources for energy purposes in an excessive amount which results in the release of greenhouses like carbon dioxide, methane, nitrous oxide, water vapor, and fluorinated gases (which are synthetic). The study results have indicated that real per capita income has a positive impact on greenhouse gas emissions. These results are in line with the previous study of Sinha et al. (2017), which analyses that the increased use of natural resources, non-reneable energy consumption, high level of productivity, and increased transportations within the country as a result of increase in the real per capita output leads to the emission of a large amount of greenhouse gases, causing environmental deterioration. The study results have shown that human capital index has a negative impact on greenhouse gas emissions. These results are in line with the previous study of Ahmed et al. (2020), which states that an increase in the education, and trianing for the employees to deal with their duties in such a way as to cause minimum emission of green house gases like CO2, methane, and nitrous oxide, reduces the level of environmental pollution.

6. CONCLUSION AND IMPLICATIONS

Within individual economies, higher levels of industrialization and urbanization majorly contribute to economic growth and progress. However, at the same time, there is a growing concern for their environmental impact in terms of sustainability and adverse effect as well. For this reason and based on the key gaps in the present literature, this study has been carried out to analyze the impact of industrialization, urbanization, and income inequality along with real per capita output and human capital index on the environmental sustainability measures in terms of carbon emission. Panel data for six ASEAN member states is collected and empirically tested. The study results have led to some interesting pieces of evidence. For example, it is found that when CO2 emissions from transport (% of total fuel combustion) is considered as the main dependent variable, the impact from industrialization is highly significant and direct. However, on the other side, urbanization and HCI are found to be negative and significant determinants of CO2 emissions. When the impact of all selected variables like industrialization, urbanization, income inequality, real capita output, and human capital index is observed for nitrous oxide emissions, it is found that industrialization is directly linked with environmental sustainability. Meanwhile, the impact from HCI is also positively significant. At the same time, the rest of the variables have shown an insignificant impact on the second measure of environmental sustainability. Observing the third measure of environmental sustainability, it is found that there is a direct impact from both industrialization and income inequality on the log of total greenhouse gas emissions measured through kt of carbon dioxide equivalent. The above findings justify the argument that more attention

is required on the direct and significant impact of industrialization for more serious environmental concerns like carbon and greenhouse gas emissions in ASEAN. In this regard, the United Nations Sustainability Goals should be taken under consideration as these goals can act as a guiding framework. Additionally, the stated framework of the U.N may create a good linkage between environmental protection measures and helping achieve inclusive growth through the reduction of inequality along with lower carbon emission.

Although the present study contributes to the existing literature in a number of ways, only some of these are highlighted . For example, the present study contributes to the theoretical discussion on the association between the environmental sustainability concern, industrialization, urbanization, real capita output, and human capital index. This can offer a more enriched understanding for those who are dealing with the various economic dynamics and their environmental impact, like policy-makers, researchers, and energy experts as well. Additionally, this study has provided a significant empirical framework for exploring the practical relationship between the study variables. However, various limitations should also be noted while reviewing the present study. These limiations exist in terms of targeting only six economies out of the whole ASEAN region, applying traditional panel regression models, missing some descriptive details of the data and study variables, and applying some robust checks as well. This means that future studies are encouraged to cover the gap by addressing these limitations. Lastly, this study has offered a number of practical inisghts and implications, specifically in the context of ASEAN economies.

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