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Natural Environment and Circular Economy? Contemporary Findings from ASEAN

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This study examines the relationship between the natural environment and the circular economy in the ASEAN region. For better understanding, factors like carbon emission, renewable energy consumption, total natural resource rent, and plant species are selected to reflect the idea of the natural environment. For the circular economy (CE), generation of municipal waste per capita, generation of municipal waste per GDP, and generation of waste per DMC are calculated as direct measures. For the empirical investigation, panel regression models like OLS regression, fixed effect, and random effect models are applied while comparing their coefficients through Hausman and Lagrange Multiplier tests. It is found that carbon emission (factors 1), and renewable energy consumptions have shown their significant influence. Whereas, for the generation of waste (per GDP), there is significant and positive influence from TNRR and significant and negative from TNRR and NOE, under a full sample of the study. For the third indicator of CE (generation of waste per DMC), the effect of GHGE, REC is positively significant, but through PS, the effect is positive and significant (only in OLS regression estimator). Additionally, this study has considered the first and second log difference for all three measures of CE with the causal impact from all indicators of the natural environment. This study has reasonably provided a significant and contemporary addition to the literature of the circular economy and environment for both developed and developing economies. Additionally, study findings are providing an excellent understanding for study of the relationship between

environmental factors and CE in ASEAN. It is highly recommended that students in the relevant fields, academics, and researchers should use this research as documented evidence.

Key words: *circular economy, natural environment, panel regression, ASEAN.*

Introduction and Background of the Literature

The circular economy (CE) has many dimensions. However, in the literary context, it enlightens the responsible usage of various resources (Ghisellini, Cialani, & Ulgiati, 2016; Kamran & Omran, 2018; Lacy & Rutqvist, 2016; Tukker, 2015). For the stimulation of the economy and in lowering the burden on the natural environment, the circular economy is observed as a core policy (Callan & Thomas, 2013; Giljum, Hak, Hinterberger, & Kovanda, 2005; Mäler, 2013; Perman, Ma, McGilvray, & Common, 2003; Zhu, Geng, & Lai, 2010). For this purpose, various studies have explained the concept of circular economy under the shadow of lowering waste or generating minimum levels of waste (Jurgilevich et al., 2016; Tisserant et al., 2017; Veleva, Bodkin, & Todorova, 2017). A range of measures in the existing literature is available to reflect the concept of the circular economy. Some are direct, while others are compiled under the title of indirect indicators for CE. Meanwhile, CE strategies are primarily integrated with both grey and scientific literature (Merli, Preziosi, & Acampora, 2018), as such planning can also play a useful role for the innovative business models which can work beyond the product preservation. In this regard, product service systems can be considered as an essential and significant instrument to promote CE (Ghisellini et al., 2016).

In the field of the industrial economy, CE is believed to be a beneficial element for the society and economy as a whole (Geissdoerfer, Savaget, Bocken, & Hultink, 2017; Pomponi & Moncaster, 2017). However, a common notion is that benefits can only be achieved with the minimisation of the virgin material for various economic activities in a region. Besides, the assumed benefits from the CE may come from minimising the loss of the material too. Various adherents who are associated with the CE are strong opponents for the material re-usage and its recycling. However, in case of market economy, both the cost of material and natural resources are not the same over time (Pigou, 2017; Tietenberg & Lewis, 2016).

The concept of the natural environment has many dimensions. Usually, the word environment encompasses the natural component of the earth like water, air, and soils (Goudie, 2018; Sauvé, Bernard, & Sloan, 2016). However, all the processes which are occurring in the earth are also classified under the title of environment. In this regard, human activities are impacting significantly on all these factors. Additionally, environmental protection and environmental science integrate the research for the protection and solution of various issues

of natural environment (Sauvé et al., 2016). The fields of natural environment, sustainable development, and environmental protection are under significant attention of the researchers. This study has investigated the empirical relationship between the natural environment and the circular economy in the region of ASEAN after observing a significant gap in the literature. The rest of the paper is structured as follows: section two defines the variables and their operational measurement., section three describes the research methods, section four provides the results and their discussion. The final section concludes the study.

Variable Measurement

For the measurement of the natural environment, this study has observed eight indicators. For a better understanding, Table 1 below explains the key titles of indicators for the natural environment. It is found that for carbon emissions, three factors like carbon emissions from transport, carbon emissions from other sectors, and carbon emissions from manufacturing industries are under observation. For the measurement of the circular economy (CE), this study has observed three direct measures: generation of waste per capita, generation of the waste per GDP, generation of waste per DMC. Data for these variables are calculated from various online and individual country-related sources from 2000 to 2017.

Table 1: Variable Nature, Title and Measurement

Variable Nature	Title and Abbreviation	Measurement
Independent: Natural Environment	CO2 emissions from transport , CO2EM1	CO2 emissions from transport (% of total fuel combustion)
	CO2 emissions from other sectors, excluding residential buildings and commercial and public services CO2EM2	CO2 emissions from other sectors, excluding residential buildings and commercial and public services (% of total fuel combustion)
	CO2 emissions from manufacturing industries and construction CO2EM3	CO2 emissions from manufacturing industries and construction (% of total fuel combustion)
	Total greenhouse gas emissions (% change from 1990), GHGE	Total greenhouse gas emissions (% change from 1990)
	Renewable energy consumption, REC	Renewable energy consumption (% of total final energy consumption)
	Nitrous oxide emissions	Nitrous oxide emissions

	(thousand metric tons of CO2 equivalent), NOE	(thousand metric tons of CO2 equivalent)
	Plant species (higher), threatened, PS	Plant species (higher), threatened
Dependent: Circular Economy	Generation of municipal waste per capita, GMWPC	Generation of municipal waste per capita
	Generation of waste per GDP, GWPGDP	Generation of waste per GDP
	Generation of waste per DMC, GWPDMC	Generation of waste per GDP, GWPGDP

Research Methods

Due to the panel in nature, this study has collected the data for five ASEAN economies. namely: Indonesia, Malaysia, Thailand, Singapore, and Laos. Both units of observation (countries in current study) and time duration (2000-2017) reflect the fact that data nature is panel. For this purpose, panel regression models like OLS, fixed effect, and random effect are applied, based on the following regression equations. For all three measures of CE, panel regression equations are developed (OLS, Fixed effect, and random effect). Equation 1-3 covers the relationship for GMWPC. Equation 4-6 and 7-9 are developed for the second and third measure of CE as explained under the variable measurement portion.

$$Y(\text{GMWPC}, \text{L1GMWPC}, \text{L2GMWPC},) = \partial + \beta_1 CO2EM1 + \beta_2 CO2EM2 + \beta_3 CO2EM3 + \beta_4 GHGE + \beta_5 REC + \beta_6 TNRR + \beta_7 NOE + \beta_8 PS + \varepsilon$$

Equation 1: OLS for Ist measure of CE

$$Y(\text{GMWPC}, \text{L1GMWPC}, \text{L2GMWPC},) = \partial + \beta_1 CO2EM1 + \beta_2 CO2EM2 + \beta_3 CO2EM3 + \beta_4 GHGE + \beta_5 REC + \beta_6 TNRR + \beta_7 NOE + \beta_8 PS + \partial_2 CID_{2it} + \partial_5 CID5_{5it} + \varepsilon_{it}$$

Equation 2: Fixed Effect for Ist measure of CE

$$Y(\text{GMWPC}, \text{L1GMWPC}, \text{L2GMWPC},) = \partial + \beta_1 CO2EM1 + \beta_2 CO2EM2 + \beta_3 CO2EM3 + \beta_4 GHGE + \beta_5 REC + \beta_6 TNRR + \beta_7 NOE + \beta_8 PS + U_i + W_{ij}$$

Equation 3: Random Effect for Ist measure of CE

$$Y(\text{GEPGDPC}, \text{L1GWPGDP}, \text{L2GWPGDP},) = \partial + \beta_1 CO2EM1 + \beta_2 CO2EM2 + \beta_3 CO2EM3 + \beta_4 GHGE + \beta_5 REC + \beta_6 TNRR + \beta_7 NOE + \beta_8 PS + \varepsilon$$

Equation 4: OLS for 2nd measure of CE

$$Y(\text{GWPGDP}, \text{L1GWPGDP} + \text{L2GWPGDP},) = \partial + \beta_1 CO2EM1 + \beta_2 CO2EM2 + \beta_3 CO2EM3 + \beta_4 GHGE + \beta_5 REC + \beta_6 TNRR + \beta_7 NOE + \beta_8 PS + \partial_2 CID_{2it} + \partial_5 CID5_{5it} + \varepsilon_{it}$$

Equation 5: Fixed Effect for 2nd measure of CE

$$Y(\text{GWPGDP}, \text{L1}GDWGDP, \text{L2GWPGDP},) = \partial + \beta_1 CO2EM1 + \beta_2 CO2EM2 + \beta_3 CO2EM3 + \beta_4 GHGE + \beta_5 REC + \beta_6 TNRR + \beta_7 NOE + \beta_8 PS + U_i + W_{ij}$$

Equation 6: Random Effect for 2nd measure of CE

$$Y(\text{GWPDMC}, \text{L1GWPDMC}, \text{L2GWPDMC},) = \partial + \beta_1 CO2EM1 + \beta_2 CO2EM2 + \beta_3 CO2EM3 + \beta_4 GHGE + \beta_5 REC + \beta_6 TNRR + \beta_7 NOE + \beta_8 PS + \varepsilon$$

Equation 7: OLS for 3rd measure of CE

$$Y(\text{GWPGDP}, \text{L1GWPGDP} + \text{L2GWPGDP},) = \partial + \beta_1 CO2EM1 + \beta_2 CO2EM2 + \beta_3 CO2EM3 + \beta_4 GHGE + \beta_5 REC + \beta_6 TNRR + \beta_7 NOE + \beta_8 PS + \partial_2 CID_{2it} + \partial_5 CID5_{5it} + \varepsilon_{it}$$

Equation 8: Fixed Effect for 3rd measure of CE

$$Y(\text{GWPGDP}, \text{L1}GDWGDP, \text{L2GWPGDP},) = \partial + \beta_1 CO2EM1 + \beta_2 CO2EM2 + \beta_3 CO2EM3 + \beta_4 GHGE + \beta_5 REC + \beta_6 TNRR + \beta_7 NOE + \beta_8 PS + U_i + W_{ij}$$

Equation 9: Random Effect for 3rd measure of CE

After analysing the above regression equations, the comparison between the fixed effect and random effect is made. For this purpose, the Hausman test is applied, considering the null hypothesis in favour of the random effect, while alternative for the fixed effect. After the Hausman test, the Lagrange Multiplier test is applied, covering the comparative analysis for the random effect and simple OLs regression estimator. For this purpose, H0 considers the fact that the OLs estimator is good for decision making, while H1 accepts the regression findings for the random effect. Findings are presented below.

Results and Discussion

Table 2 provides the findings for all three panel regression models (OLS, fixed effect, and random effect). It is observed that the effect of COEM1 on the generation of municipal waste per capita is -0.0870 with the standard error of 0.0230. It shows that there is a negative and highly significant influence of carbon emission on CE in the ASEAN region. Model 1 has predicted this effect while applying the simple OLS regression. More specifically, it is inferred that the more emissions in the form of CO2 in ASEAN, the more adverse the impact on generation of municipal waste per capita (direct measure of CE). However, through second and third proxies of CO2 emissions, the effect through OLS regression on CE is found to be insignificant. It means that there is no influence of CO2EM2 and CO2EM3 on CE in

ASEAN economies. Through greenhouse gas emissions (GHGE), it is found that the effect on GMWPC is positively insignificant at 10 percent under the pooled OLS regression Model 1. However, the effect through renewable energy consumption (REC) is 0.988 with the standard error of 0.188, significant at 1 percent. It means that with more consumption of energy in terms of renewable resources, there will be a positive and direct influence on the value of CE as measured through generation of municipal waste per capita in all five ASEAN members. In addition, the environmental effect in terms of total natural resource rent (TNRR), coefficient is 0.738, showing its positive but insignificant influence under OLS regression findings. It means that there is no influence of total natural resource rent on CE of ASEAN region. The same effect is observed for the remaining two measures of the natural environment in terms of nitrous oxide emissions (NOE), and plant species (PE). It explains that there is no influence of these indicators on GMWPC.

Model 2 predicts the effect of explanatory variables on GMWPC as a direct measure of CE through the fixed effect method. It is found that the effect of CO2EM1 is 0.0849, significant at 1 percent, showing a direct impact. It means that the more the COEM1 in ASEAN, the more the direct influence on CE as presented under Table 2. However, through the remaining two measures of COEEM, their impact is positive but insignificant under the full sample of the study. Meanwhile, REC has shown its positive and significant impact of 2.006 at 5 percent chance of error. The rest of the indicators (Model 2) have shown their insignificant influence on the value of GMWPC. As per the findings under Model 3, the random effect method is applied. It is found that CO2EM1 has its positive and highly significant influence on CE with the coefficient of 0.9682, while nitrous oxide emissions have also shown a positive impact with a coefficient of 0.738. It means that both the carbon emissions and nitrous oxide emissions are directly impacting on generation of the municipal waste per capita in ASEAN. As per the explanatory power, Model 1 under OLS regression has shown the highest variation of 63 percent, followed by Model 2; 62.2 percent respectively.

Table 2: Impact of Environmental factors on CE (GMWPC)

	Generation of municipal waste per capita	Generation of municipal waste per capita	Generation of municipal waste per capita
VARIABLES	OLS: Model 1	Fixed Effect: Model 2	Random Effect:Model 3
CO2EM1	-0.0870***	0.0849***	0.9682***
	(0.0230)	(0.00852)	(0.2340)
CO2EM2	0.000157	0.00340	0.000157
	(0.000753)	(0.00342)	(0.000753)
CO2EM3	-4.50e-07	-2.36e-06	-4.50e-07

	(3.57e-07)	(1.46e-06)	(3.57e-07)
GHGE	1.755	1.584	1.755
	(1.773)	(1.762)	(1.773)
REC	0.988***	2.006**	0.988
	(.188)	(.871)	(0.868)
TNRR	1.730	1.561	1.730
	(1.777)	(1.766)	(1.777)
NOE	0.738	0.575	.738**
	(.776)	(.765)	(.326)
PS	1.964	1.785	1.964
	(1.820)	(1.809)	(1.820)
Constant	-173.1	-156.8	-173.1
	(126.8)	(96.7)	(177.8)
Observations	90	90	90
R-squared	0.630	0.622	0.578
Number of Country IDs	5	5	5

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 3 considers the difference in both the coefficients as presented under fixed effect and random effect for their comparison. For this purpose, the Hausman test is applied, considering the H0 that random effect is more appropriate, while H1 indicates the fact that the fixed effect is better than the random effect. After finding the difference between both coefficients, the value of significance for chi2bar is presented under similar Table 2. It is found that the probability value is insignificant at 5 percent (0.599), meaning that Ho is accepted. In the very next step, comparison is conducted between the random effect and OLS regression estimator. For this purpose, the Breusch and Pagan Lagrangian multiplier test is applied and it is found that the value of chi2bar is significant at five percent. It shows that the preferred model between random and OLs is random effect for the final consideration.

Table 3: HM and LM test for the comparison between the Panel Models

Variables	**fixed**	**random**	**Difference**
CO2EM1	0.0849	0.9682	-0.8833
CO2EM2	0.0034	0.000157	0.003243
CO2EM3	-2.36E-06	-4.50E-07	-1.9E-06
GHGE	1.584	1.755	-0.171
REC	2.006	0.988	1.018
TNRR	0.575	0.738	-0.163
NOE	1.561	1.73	-0.169
PS	1.785	1.964	-0.179

Hausman (1978) specification test
chi2(7) =
5.57
Prob>chi2 = 0.5904
Breusch and Pagan Lagrangian multiplier test for random effects Chibar2= 6.3652
Prob>chi2 = 0.015**

Table 4 provides the empirical findings for the impact of environmental factors on the second measure of CE as measured through the generation of waste per GDP. It is found that all three factors of CO2EM have shown their insignificant influence on CE. This means that carbon emission factors are not impacting on CE in terms of generation of waste per GDP in ASEAN. However, the factor of GHGE has shown its significant and positive influence in all threepanel models at 1 percent chance of error, which means that GHGE is directly impacting on the value of second measure of CE. REC is negatively but insignificantly impacting on CE under OLS, while negatively and significantly impacting under both fixed and random effect findings. It means that there is an adverse influence of GHGE on the value of GWPGDP.

Similarly, the effect of TNRR is highly significant and negative in all three regression findings, while through nitrous oxide emissions, the impact on second indicator of CE is NOE under all panel models. Plant species have provided the fact that there is a negative and highly significant impact on CE with the coefficients of -2.34, -6.82, and-5.34 respectively.

In addition, Table 5 provides the difference between the coefficients of fixed and random effects. It is found that the HM test indicates a significant value of chi2bar, accepting the fact that fixed effect findings are more appropriate for generalising the effect of explanatory variables on the second measure of CE.

Table 4: Impact of Environmental factors on CE (GMWGDP)

	Generation of waste per GDP	Generation of waste per GDP	Generation of waste per GDP
VARIABLES	Model 1	Model 2	Model 3
CO2EM1	0.00214	-0.0141	0.00214
	(0.0111)	(0.0631)	(0.0175)
CO2EM2	0.000695	0.00126	0.000695
	(0.00140)	(0.0254)	(0.00572)
CO2EM3	2.83e-06	6.40e-06	2.83e-06
	(2.93e-06)	(1.08e-05)	(2.71e-06)
GHGE	95.64***	93.23***	95.64***

	(30.66)	(13.05)	(13.47)
REC	-29.56	-29.12**	-29.56**
	(34.03)	(13.86)	(14.34)
TNRR	-5.67***	-3.26***	-5.67***
	(1.85)	(0.108)	(1.50)
NOE	-9.01***	-1.65***	-4.01***
	(1.75)	(0.07)	(1.949)
PS	-2.34***	-6.82***	-5.34***
	(0.83)	(2.40)	(1.83)
Constant	9.605***	9.369***	9605***
	(3.082)	(2.309)	(2.351)
Observations	90	90	90
R-squared	0.684	0.678	0.715
Number of CID	5	5	5

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 5: HM and LM test for the comparison between the Panel Models

Variables	**fixed**	**random**	**Difference**
CO2EM1	-0.01413	0.00214	-0.01627
CO2EM2	0.001264	0.000695	0.000569
CO2EM3	6.40E-06	2.83E-06	3.57E-06
GHGE	93.2292	95.6437	-2.414414
REC	-29.1171	-29.5639	0.446808
TNRR	-5.67	-3.26	-2.41
NOE	-9.01	-1.65	-7.36
PS	-2.34	-6.82	4.48
Hausman (1978) specification test			
chi2(7) = (b-B)'[(V_b-V_B)^(-1)](b-B)			
= 8.175			
Prob>chi2 = 0.015**			

Table 6 provides the panel regression output for the third measure of CE in terms of generation of the waste per DMC in the ASEAN region. It is observed that all three factors of carbon emissions have shown their insignificant influence on CE (3rd measure) in Model 1, Model 2, and finally the Model 3 respectively. The effect through GHGE under pooled OLS, coefficient of -5.527 indicates an adverse and negative influence and the same is experienced in both fixed and random effect regression findings. Meanwhile, the effect through

renewable energy consumption REC on GWPDMC is highly significant and negative, which shows its adverse impact on CE under the full sample of the study. However, the effect through TNRR and NOE is insignificant, meaning that there is no significant influence of both of these factors on the third indicator of CE in ASEAN. Additionally, PS has a highly significant and positive influence on GWPDMC, with a coefficient of 4.464 under Model 1 (OLS regression estimation). However, findings under the fixed and random effects are found to be insignificant for the PS-GWDPMC relationship, as presented under Table 7.

Table 6: Impact of Environmental factors on CE (GWPDMC)

	(Generation of waste per DMC)	(Generation of waste per DMC)	(Generation of waste per DMC)
VARIABLES	Model 1	Model 2	Model 3
CO2EM1	0.00176	-0.0177	0.00176
	(0.00388)	(0.0211)	(0.00562)
CO2EM2	-0.000385	-0.00739	-0.000385
	(0.000542)	(0.00848)	(0.00184)
CO2EM3	8.54e-07	4.46e-06	8.54e-07
	(7.32e-07)	(3.63e-06)	(8.72e-07)
GHGE	-3.980***	-3.712**	-3.980***
	(.802)	(1.365)	(.325)
REC	-5.527***	-5.584***	-5.527***
	(2.916)	(1.636)	(1.604)
TNRR	-3.929	-3.665	-3.929
	(4.799)	(4.375)	(4.334)
NOE	-3.973	-3.720	-3.973
	(4.807)	(4.372)	(4.332)
PS	4.464***	-4.184	-4.464
	(1.859)	(4.482)	(4.439)
Constant	492.9	467.6	492.9
	(480.6)	(437.8)	(433.7)
Observations	90	90	90
R-squared	0.584	0.762	0.642
Number of CID	5	5	5

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 7: HM and LM test for the comparison between the Panel Models

Variables	**fixed**	**random**	**Difference**
CO2EM1	-0.01769	0.001761	-0.01945
CO2EM2	-0.00739	-0.00039	-0.00701
CO2EM3	4.46E-06	8.54E-07	3.61E-06
GHGE	-3.71215	-3.97956	0.267419
REC	-5.58352	-5.52658	-0.05694
TNRR	-3.66471	-3.9292	0.264487
NOE	-3.71979	-3.97298	0.253193
PS	-4.18355	-4.46448	0.280928
Hausman (1978) specification test			
chi2(7) = 52.35***			
Prob>chi2 = 0.001			

Table 8 considers the effects of environmental factors on the log value of the first measure of CE (GMWPC). It is observed that the significant indicators for the GMWC (after taking the first log) are TNRR, and PS, showing their positive and highly significant impact. This means that factors like total natural resource rent (TNRR) and plant species are positively and significantly impacting on the value of the first log of GMWC. Meanwhile, the rest of the indicators as presented under Table 8 have shown their insignificant impact. For finally accepting the regression findings, the HM test indicates that the fixed effect model is more appropriate (i.e. chi2bar is significant at 5 percent chance of error).

Table 8: Impact of Environmental factors on CE (L1-GMWPC)

	L1-GMWC	L1-GMWC	L1-GMWC
VARIABLES	Model 1 (OLS)	Model 2 (Fixed Effect)	Model 3 (Random Effect)
CO2EM1	-0.00119	0.0106	-0.00119
	(0.00168)	(0.00870)	(0.00236)
CO2EM2	0.000207	0.00480	0.000207
	(0.000209)	(0.00358)	(0.000742)
CO2EM3	-5.39e-07	-2.82e-06	-5.39e-07
	(3.41e-07)	(1.92e-06)	(3.58e-07)
GHGE	1.806	1.619	1.806
	(3.140)	(1.773)	(1.754)

REC	2.449	2.281	2.449
	(4.239)	(1.938)	(1.922)
TNRR	1.953***	1.757***	1.953***
	(0.145)	(.783)	(.763)
NOE	1.900	1.713	1.900
	(3.141)	(1.780)	(1.760)
PS	2.037**	1.847**	2.037**
	(1.010)	(.818)	(0.799)
Constant	-187.7	-169.2	-187.7
	(314.9)	(178.1)	(176.1)
Observations	85	85	85
R-squared	0.963	0.597	.452
Number of CID	5	5	5
Hausman (1978) specification test chi2(7) = 15.36 Prob>chi2 = 0.025**			

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9 indicates the fact that for the second log of GMWC as the main dependent variable, the effect of carbon emissions (third indicator) is found to be negatively significant under OLS, fixed effect and random effect models. It means that COEM2 is negatively and significantly affecting the value of L2-GMWC in the ASEAN region. However, the remaining two indicators of carbon emissions have shown their insignificant impact on GMWC. Besides, factors like GHGE, TNRR, NOE, and PS have shown their positive/negative but insignificant impact on the L2 measure of GMWC in ASEAN. However, under random effect findings, the effect of renewable energy consumption REC on L2-GMWC is negatively significant at 10 percent. Finally, the value of the HM test is significant at 5 percent, showing the fact that fixed effect coefficients are more appropriate.

Table 9: Impact of Environmental factors on CE (L2-GMWPC)

	L2 GMWC	L2 GMWC	L2 GMWC
VARIABLES	Model 1	Model 2	Model 3
CO2EM1	-0.00207	0.00673	-0.00207
	(0.00165)	(0.00815)	(0.00231)
CO2EM2	0.000106	0.00369	0.000106
	(0.000185)	(0.00334)	(0.000679)
CO2EM3	-7.09e-07**	-2.87e-06*	-7.09e-07**
	(3.24e-07)	(1.48e-06)	(3.35e-07)

GHGE	0.105	0.219	0.105
	(2.293)	(1.732)	(1.713)
REC	-3.777	-3.529	-3.777*
	(3.174)	(2.239)	(2.209)
TNRR	0.279	0.389	0.279
	(2.302)	(1.740)	(1.720)
NOE	0.236	0.350	0.236
	(2.298)	(1.737)	(1.718)
PS	0.154	0.273	0.154
	(2.358)	(1.779)	(1.759)
Constant	-18.66	-30.21	-18.66
	(230.2)	(173.9)	(172.0)
Observations	80	80	80
R-squared	0.170	0.193	0.183
Number of CID	5	5	5
Hausman (1978) specification test chi2(7) = 19.42 Prob>chi2 = 0.019**			

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 10 considers the effect of environmental factors on the log value of the second measure of CE (GWPGDP). It is observed that the significant indicators for the GWPGDP (after taking the first log) are CO2M3, TNRR, REC, NOE, and PS, showing their mixed (positive and negative), and highly significant impact. This means that these factors are reasonably influential on GWPGDP as a direct measure of CE. Meanwhile the rest of the indicators have shown their insignificant impact. For finally accepting the regression findings, the HM test indicates that the fixed effect model is accepted for the decision making.

Table 10: Impact of Environmental factors on CE (L1-GWPGDP)

	L1 GWPGDP	L1 GWPGDP	L1 GWPGDP
VARIABLES	Model 1	Model 2	Model 3
CO2EM1	0.00830	-0.0304	0.00830
	(0.0101)	(0.0503)	(0.0139)
CO2EM2	0.000601	-0.00951	0.000601
	(0.00135)	(0.0207)	(0.00439)
CO2EM3	4.75e-06*	4.10e-06	4.75e-06**
	(2.64e-06)	(8.82e-06)	(2.12e-06)
GHGE	-93.26***	-91.35***	-93.26***

	(18.63)	(10.25)	(10.37)
REC	-47.97**	-46.61***	-47.97***
	(18.63)	(11.21)	(11.37)
TNRR	-94.11***	-92.15***	-94.11***
	(18.72)	(10.31)	(10.42)
NOE	-92.23***	-90.33***	-92.23***
	(18.67)	(10.29)	(10.41)
PS	-96.07***	-94.11***	-96.07***
	(19.37)	(10.52)	(10.64)
Constant	9,406***	9,216***	9,406***
	(1,872)	(1,030)	(1,041)
Observations	85	85	85
R-squared	.681	.635	.782
Number of CID	5	5	5
Hausman (1978) specification test chi2(7) = 21.42 Prob>chi2 = 0.002***			

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 11 displays the fact that the significant determinants for GWPGDP (2nd log) are: CO2EM3, GHGE, TNRR, NOE, and PS, respectively. It means that there is an adverse influence of all of these indicators on the value of L2GWPGDP in all five regions of ASEAN. However, the first and second indicators of carbon emissions have shown their insignificant influence on the value of L2-GWPGDP. In addition, the HM test provides the favour for the fixed effect coefficients.

Table 10: Impact of Environmental Factors on CE (L2-GWPGDP)

	L2 GWPGDP	L2 GWPGDP	L2 GWPGDP
VARIABLES	Model 1	Model 3	Model 2
CO2EM1	0.00828	0.00828	-0.0562
	(0.0111)	(0.0145)	(0.0498)
CO2EM2	-0.000126	-0.000126	-0.0219
	(0.00134)	(0.00428)	(0.0204)
CO2EM3	4.93e-06*	4.93e-06**	5.09e-06
	(2.74e-06)	(2.11e-06)	(9.02e-06)
GHGE	-65.87***	-65.87***	-65.74***
	(12.05)	(10.80)	(10.58)
REC	-0.273	-0.273	-2.082

	(15.93)	(13.92)	(13.68)
TNRR	-66.47***	-66.47***	-66.29***
	(11.99)	(10.84)	(10.63)
NOE	-64.70***	-64.70***	-64.56***
	(12.02)	(10.83)	(10.61)
PS	-68.01***	-68.01***	-67.89***
	(12.32)	(11.08)	(10.86)
Constant	6.647***	4.647***	6.636***
	(3.203)	(1.084)	(1.062)
Observations	80	80	80
R-squared	0.658	0.521	0.639
Number of CID	5	5	5
Hausman (1978) specification test chi2(7) = 17.42, Prob>chi2 = 0.0253**			

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 12 indicates the effect of selected environmental factors on the third measure of CE, as observed while taking the first log. It is found that carbon emission factors have no significant influence on l1-GWPDMC in all threepanel models. Meanwhile, significant and negative influences are only observed through TNRR and PS on L1-GWPDMC in all five ASEAN economies. Therefore, the more the TNRR and PS in the ASEAN region, the greater the adverse impact on the CE factor. For the effect of GHGE, REC, and NOE, an insignificant impact on L1-GWPDMC is noted. For the HM test, findings are again in favour of the fixed effect coefficients. Table 13 considers the effects of selected regressors on L2-GWPDMC. It is found that only the effect of renewable energy consumption on L2-GWPDMC is highly significant under OLS, fixed effect and random effect models.

Table 12: Impact of Environmental factors on CE (L1 GWPDMC)

	(L1 GWPDMC)	(L1 GWPDMC)	(L1 GWPDMC)
VARIABLES	Model 1	Model 2	Model 3
CO2EM1	0.00215	-0.0219	0.00215
	(0.00413)	(0.0217)	(0.00581)
CO2EM2	-0.000531	-0.0104	-0.000531
	(0.000489)	(0.00893)	(0.00183)
CO2EM3	9.67e-07	5.21e-06	9.67e-07
	(7.81e-07)	(3.80e-06)	(8.83e-07)
GHGE	-2.476	-2.322	-2.476
	(6.682)	(4.421)	(4.322)
REC	-4.994	-4.844	-4.994

	(8.779)	(4.834)	(4.736)
TNRR	-2.797***	-2.631***	-2.797***
	(.693)	(.446)	(.343)
NOE	-2.707	-2.553	-2.707
	(6.683)	(4.438)	(4.337)
PS	-2.988***	-2.833***	-2.988*
	(0.922)	(0.534)	(0.432)
Constant	363.0	348.1	363.0
	(670.1)	(444.1)	(434.0)
Observations	85	85	85
R-squared	0.485	0.335	0.397
Number of CID	5	5	5
Hausman (1978) specification test chi2(7) = 25.56, Prob>chi2 = 0.003**			

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 13: Impact of Environmental factors on CE (L2-GWPDMC)

	(L2 GWPDMC)	(L2 GWPDMC)	(L2 GWPDMC)
VARIABLES	Model 1	Model 2	Model 3
CO2EM1	0.00386	-0.0133	0.00386
	(0.00412)	(0.0211)	(0.00594)
CO2EM2	-0.000306	-0.00784	-0.000306
	(0.000463)	(0.00866)	(0.00175)
CO2EM3	1.30e-06	4.80e-06	1.30e-06
	(7.80e-07)	(3.83e-06)	(8.63e-07)
GHGE	0.968	0.658	0.968
	(5.548)	(4.492)	(4.411)
REC	9.067***	8.802***	9.067
	(2.492)	(2.806)	(3.687)
TNRR	0.601	0.286	0.601
	(5.574)	(4.510)	(4.428)
NOE	0.661	0.347	0.661
	(5.562)	(4.504)	(4.422)
PS	0.888	0.569	0.888
	(5.724)	(4.611)	(4.528)
Constant	20.06	51.72	20.06
	(557.2)	(450.9)	(442.7)
Observations	80	80	80
R-squared	0.107	0.189	0.124

Number of CID	5	5	5
Hausman (1978) specification test			
chi2(7) = 10.35, Prob>chi2 = 0.3904			
Breusch and Pagan Lagrangian multiplier test for random effects Chibar2= 9.258, Prob>chi2 = 0.019**			

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Conclusion and Recommendations

This study has investigated the relationship between natural environmental indicators and a circular economy in the region of ASEAN. For the empirical investigation, panel analysis with OLS, fixed effect, and random effect are conducted, and results are presented. It is observed that for the CE in terms of generation of municipal waste per capita, significant determinants are the CO2 emissions from transport (% of total fuel combustion) and renewable energy consumption. For the CE in terms of generation of waste per GDP, it is found that there is a significant influence from GHGE, TNRR, NOE, and PS under the full sample of the study. For the third indicator of CE (generation of waste per DMC), there is a significant impact of GHGE, REC, and PS. After the consideration of the direct indicators of CE, this study has observed first and second logs for all of these outcome factors, and the same panel regression models are applied to check whether there is any relationship between them or not. For L1-GMWC, a significant influence is observed from factors like TNRR and PS respectively in all the panel models. Similarly, for L2-SMWC, there is a significant impact of CO2EM3, while the remaining indicators have shown their insignificant impact under the full sample of the study. In addition, for L1-GWPGDP there is a significant influence from all the environmental factors, except carbon emissions (1-2). For L2-GWPGDP, significant influence is observed from the third indicator of carbon emissions, GHGE, TNRR, NOE, and FS. For L1-GPDMC, only the factors TNRR and PS have shown their negative and highly significant influence in ASEAN. However, for L2-GPDMC, only the REC has shown its significant and positive influence, both in OLS and fixed effect models. This study has provided a significant and contemporary addition to the literature of circular economy and environment for both developed and developing economies. Additionally, study findings provide an excellent understanding for studying the relationship between environmental factors and CE in ASEAN. It is highly recommended that students in the relevant fields, academics, and researchers should use this research as documentary evidence.

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