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The impact of transport energy consumption and foreign direct investment on CO_2 emissions in ASEAN countries

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This study assesses the impact of foreign direct investment (FDI) and the energy consumption of the transport sector on CO_2 emissions in five ASEAN (Association of Southeast Asian Nations) countries for the period 1980–2019. The study employs the environmental Kuznets curve (EKC), and uses a nonlinear autoregressive distributive lag model (NARDL) to analyze the data. The results suggest that carbon emissions and their determinants have a long-run equilibrium cointegrated relationship. Findings reveal that the EKC relation between income and CO_2 emissions holds only for Singapore, whereas for Indonesia, Malaysia, the Philippines, and Thailand, income growth impacts CO_2 emissions positively. Foreign direct investment and energy consumption in the transport sector also significantly impact CO_2 emissions in the selected countries, except for Singapore. Transport energy consumption contributes more to CO_2 emissions than FDI. Moreover, results suggest that FDI and energy consumption-led growth models are appropriate for ASEAN economies. The study recommends cautious growth policies, clean FDI inflows, and an emphasis on energy-efficient transport systems.

KEYWORDS

foreign direct investment, transport energy consumption, CO_2 emission, ASEAN, NARDL

Introduction

The protection and preservation of the environment has become the main concern of researchers, policymakers, and environmentalists alike. Debate about the environmental impact of economic growth is not new—only now the concern has shifted to identifying the determining factors behind environmental deterioration and the direction of influence of these factors (Usman et al., 2021; Usman and Makhdum, 2021; Awan et al., 2022a; Ramzan et al., 2022; Usman and Balsalobre-Lorente, 2022; Usman and Radulescu, 2022). Identifying key factors behind environmental degradation is thus a basic prerequisite for formulating effective environmental policies.

There are many studies empirically analyzing the combined environmental impact and linkage of energy usage and economic growth, particularly on CO_2 emissions.

However, these are not the only two factors behind CO_2 emissions (Zhang, 2011). International trade, transportation, fossil fuel combustion, and foreign direct investment are the other important variables explaining damage to the natural environment (Fan et al., 2020; Yang et al., 2020a; Yang et al., 2020b; Ali and Kirikkaleli, 2022; Qayyum et al., 2021; Ali et al., 2022; Qayyum et al., 2022; Shabir et al., 2022; Yang et al., 2022; Yuan et al., 2022).

Among the important determinants of environmental degradation, transportation and foreign direct investment (FDI) are major drivers of energy consumption. The increasing influx of FDI and proliferating transportation activities play a vital role in propelling economic growth in developing nations, yet the contribution to environmental degradation has not been fully explored, especially in the context of ASEAN countries. Nevertheless, questions have been raised about the environmental consequences of increasing FDI contributions to developing nations (Ang, 2008; Acaravci and Ozturk, 2010).

Developing countries attract FDI inflows without consideration of the detrimental impact on the environment. While FDI inflows are beneficial if they bring low-carbon technologies to the host country (Zeng and Eastin, 2012), they can also harm the environment of that host (Pao and Tsai, 2011). Similarly, while the local aspects of transport-related pollution, such as air and noise pollution in urban centers, have been analyzed, the role of transportation in climate change and global warming has been largely ignored in the literature on environmental economics (Arsenio et al., 2016). Ismail et al. (2017) strongly recommend that future research should focus on the influence of increasing transportation on the environment, since the contribution of transportation to pollution has been growing over the last two decades.

The current study examines the impact of these important determinants—FDI and transportation—in five ASEAN countries from 1980 to 2019 in light of the environmental Kuznets curve (EKC) framework. The countries are Indonesia, the Philippines, Thailand, Malaysia, and Singapore. Previous studies on this issue, such as those of Poon et al. (2006), Chandran and Tang (2013), Liu et al. (2017), and Zhu et al. (2016), mostly use panel data analysis and have inconclusive findings. The current study employs time-series analysis for individual countries to avoid some of the disadvantages of panel data analysis. This analysis enables us to arrest the complexities of the income environment relation in each country in a way that panel data analysis is unable to do.

Second, previous studies have not fully explored the complex relationship between FDI and the environment, resulting in less clarity about the validity of the Pollution Haven Hypothesis (PHH)[1]. ASEAN nations have received massive FDI inflows in the past three decades, although conventional wisdom suggests that without strict environmental regulations, FDI can harm the environment of host countries (Zhang and Zhou, 2016). Nevertheless, FDI also introduces environment-friendly and energy-efficient technologies that curtail environmental degradation. Furthermore, the environmental impact of FDI is reversed when it is concentrated on the services sector. For these reasons, Zeng and Eastin (2012), claim that overall, FDI generates conditions conducive for the improvement of the environment in host countries. Given these conflicting views about the role of FDI, it is helpful to reexamine its impact on the environment in the context of ASEAN economies.

TABLE 1 Energy consumption in the transport sector in ASEAN countries in 2018.

Country	Transport energy use shares in total energy use
Malaysia	20.40
Singapore	4.02
Philippines	25.46
Indonesia	19.08
Thailand	18.38

Source: Administration, UEI (2017). Annual Energy Outlook 2017: With Projections to 2035: Government Printing Office.

Third, despite the growing importance of the transport sector, literature about its impact on the environment is scanty (Ong et al., 2012). The transport sector uses 25% of world energy (IEO, 2018) and, after electricity and industry, is the third largest source of global CO_2 emissions (IEA, 2018). This sector is also the main user of energy and a major contributor to CO_2 emissions from ASEAN countries (see Table 1). Against this backdrop, it is essential to investigate the impact of energy consumption in the transport sector on CO_2 emissions. This knowledge would be helpful in formulating specific and effective policies for the transport sectors of ASEAN nations.

The current study thus contributes to the literature by examining the impact on CO_2 emissions of FDI and transportation energy consumption in individual ASEAN countries using time-series data. A time-series analysis for each country following the NARDL approach is a unique contribution of this study. This method enables us to gauge the complex relation between emissions and their determinants in a more effective way than the panel estimation method. Besides that, legislators, climate activists, and government officials will gain from the study's findings, which provide better insight into, as well as critical facts and proof about, environmental wellbeing.

The next section reviews the existing literature. The third section describes the theoretical model, data, and methods. The fourth section discusses the results based on the techniques used,

1 PHH posits that pollution-intensive industries tend to relocate in developing countries with laxer environmental regulations than those of advanced nations.

TABLE 2 Linearity test statistic results.

Variables	Malaysia	Indonesia	Singapore	Thailand	Philippines	1%	5%	10%
CO_2	5.26*	4.10*	5.97*	3.89*	3.64*	3.76	3.56	3.46
Y	1.98*	1.79*	2.16*	2.33*	1.52*	1.43	1.37	1.33
FDI	3.86*	3.99*	3.65*	4.09*	3.62*	3.44	3.31	3.20
TEC	2.14*	2.01*	1.66*	2.53*	1.78*	1.49	1.43	1.39

Note: *, **, and *** signify the null hypothesis at 1, 5, and 10 percent.

and the final section concludes with a prospective strategy outline.

Literature review

Climate change and global warming have been intensively investigated globally in the last three decades. Carbon emission is considered the primary cause of these calamities. CO_2 is a global pollutant and is triggered in various ways, such as through the combustion of fuel from transport vehicles, power plants, factories, and households. The current study inspects the influence of FDI, economic growth, and transportation on CO_2 emissions. The empirical literature on the issue is thus branded into three different streams. First are studies examining the influence of income growth on the environment to assess the validity of the EKC hypothesis. Second are empirical works covering the link between transport and the environment, and third are empirical studies analyzing the influence of FDI on the environment, or the validity of the pollution haven hypothesis (PHH).

The empirical literature about the EKC has divided outcomes. Studies such as those of Lomborg (2001), Lantz and Martinez-Espineira (2008), Jain and Chaudhuri (2009), Jaunky (2011), Borhan et al. (2012), Chow and Li (2014), Apergis and Ozturk (2015), and Jebli et al. (2016) empirically demonstrate the legitimacy of the EKC. However, studies such as those of Khanna and Plassmann (2004), Galeotti et al. (2006), Liu (2008), Lipford and Yandle (2010), Zilio (2012), Jobert et al. (2014), and Al-Mulali et al. (2015) find empirical evidence against the existence of the EKC. Further, Gill et al. (2018a) do not recommend EKC as a growth path for developing countries.

There are also numerous studies with mixed outcomes on the income-environment relation, e.g., Cole (1999), Hettige et al. (2000), Dasgupta et al. (2002), Caviglia-Harris et al. (2009), Kijima et al. (2010), He and Richard (2010), and Zanin and Marra (2012). Similarly, Taskin and Zaim (2000), and Carvalho and Almeida (2009) find an N-shaped income-environment relation. Shahbaz and Sinha (2019) provide an empirical literature survey on the EKC for the period 1991–2017. They categorize the studies into single country and multiple country studies. The findings from both categories are inconclusive. Such discrepancies in empirical output can be attributed to different contexts, periods, choices of control variables, and methodologies of the studies. In the case of ASEAN countries, limited empirical studies have been carried out on the EKC. For instance, Zambrano-Monserrate et al. (2018) prove that income and the environment have an EKC relation in Singapore, while Gill et al. (2018b) assert that per capita income in Malaysia has reached a position where pollution starts to decline with further growth in income.

The previous literature also unfolds contrasting empirical output regarding the impact of FDI inflow on the quality of the environment in host countries. For instance, Deng and De-yong (2008), Honglei et al. (2011), Al-Mulali and Tang (2013), claim that FDI brings technologies, innovations, financial growth, and administrative skills to host countries that eventually leads to environmental improvement. By contrast, Li-wei and He (2006), Acharyya (2009), Pao and Tsai (2011), Mukherjee et al. (2013), and Shao (2017) support the PHH stance on the impact of FDI on the environment in host countries. They claim that FDI is mostly concentrated in those sectors where environmental resources are underpriced. Consequently, FDI deteriorates environmental quality in developing countries. Recently, Hanif et al. (2019) explored the inward FDI impact on the emission of CO_2 in fifteen developing nations of Asia over the period 1990–2013. They found FDI as a major source of CO_2 emission in these nations. They therefore support the PHH stance that FDI has been having a deteriorating effect on the environment of developing countries. Balsalobre-Lorente et al. (2022) add to the discussion on environmental performance in the PIIGS nations (Portugal, Ireland, Italy, Greece, and Spain), by looking at the impact of FDI on carbon emissions from 1990 to 2019. The dynamic ordinary least squares (DOLS) measure is used for empirical evaluation. The empirical findings also support the PHH, as high FDI is a major contributor to environmental deterioration in PIIGS economies. These findings encourage decision makers to put forward extensive energy and economic initiatives aimed at cleaner production activities, to improve environmental protection, and meet sustainable development goals.

The above literature indicates the controversies surrounding the PHH. The debate is still inconclusive, and additional studies in different parts of the world are required to test the PHH's claims about FDI further.

TABLE 3 Nonlinear unit root statistics.

Country	Series names	Kapetanios et al. (2003)	Kruse (2011)
Malaysia	Level		
	CO_2	−1.753	3.219
	Y	−1.005	2.168
	FDI	−0.978	4.103
	TEC	−1.235	1.258
	First Difference		
	CO_2	−2.998**	7.928*
	Y	−3.311**	8.996*
	FDI	−3.046**	11.136**
	TEC	−4.087***	14.973**
Indonesia	Level		
	CO_2	−1.220	2.331
	Y	−0.897	3.088
	FDI	−1.661	3.592
	TEC	−1.714	2.527
	First Difference		
	CO_2	−3.001**	6.999*
	Y	−2.841**	9.866*
	FDI	−2.983**	10.662**
	TEC	−3.999***	11.738**
Singapore	Level		
	CO_2	−1.749	4.333
	Y	−0.999	3.111
	FDI	−1.152	3.509
	TEC	−1.790	3.001
	First Difference		
	$C O_2$	−4.911***	8.222*
	Y	−2.995**	9.001*
	FDI	−3.161**	11.036**
	TEC	−4.006***	12.252**
Thailand	Level		
	CO_2	−1.444	3.002
	Y	−1.108	3.842
	FDI	−1.015	3.981
	TEC	−1.112	2.469
	First Difference		
	CO_2	−3.456**	7.770*
	Y	−3.884***	7.999*
	FDI	−3.010**	10.188**
	TEC	−3.891***	10.995**
Philippines	Level		
	CO_2	−1.1.559	4.001
	Y	−1.014	4.122

(Continued on following page)

TABLE 3 (*Continued*) Nonlinear unit root statistics.

Country	Series names	Kapetanios et al. (2003)	Kruse (2011)
	FDI	−1.166	5.101
	TEC	−1.550	1.472
	First Difference		
	CO_2	−3.888***	8.898*
	Y	−3.091**	7.012*
	FDI	−3.646**	11.659**
	TEC	−3.992***	13.506**

Note: *, **, *** indicate the level of significance at 10, 5, and 1 percent, respectively, using the critical values of Kruse (2011) and Kapetanios et al. (2003).

There are not many studies examining the impact of transportation on CO_2 emissions. He et al. (2005) indicate a significant contribution by the road transport industry to environmental degradation in China. Wang et al. (2011) assess the environmental effect of transportation in China, which is the largest emitter of greenhouse gases (GHG), and find the transport sector is one of the main contributors to GHG emissions. Tian et al. (2014) also study the relative pollution cost of different transport models and suggest different policy options to mitigate CO_2 emissions. Kinnear et al. (2015) also reveal a sizeable impact of diesel trucks on carbon emissions in Australia, while Garraín et al. (2016) point to the reduction in pollution from transportation resulting from the use of biofuels. Likewise, the effects of energy use in transportation on carbon emission in Tanzania for the period 1980–2014 are investigated by Talbi (2017). Their findings reveal that increased fuel prices can mitigate carbon emissions from the transport sector. Baloch (2018) examines the dynamic connection between transportation and SO_2 emissions in Pakistan from 1971 to 2014. He also confirms the significant influence of transportation on environment quality.

In sum, the above literature provides limited and inconclusive empirical evidence on the complex association between CO_2 emissions, economic growth, FDI, and transportation. Furthermore, most of the studies employ panel datasets for empirical analysis, leaving meager space for individual country analyses. The analysis of individual countries would provide more insight into the complex relationship between these variables and produce comprehensive results encouraging researchers, government institutes, and policymakers to consider cutting CO_2 emissions.

Methods

The model

According to EKC theory, there is a nonlinear quadratic relationship between economic growth and environmental degradation. Economic growth degrades the environment at the early stages of economic development; however, after reaching a certain stage, the environment starts to improve with further income growth. The EKC theory thus suggests economic growth both causes and remedies the global sustainability crises.

Most of the literature concludes energy usage, FDI, and GDP are the important determinants of rising levels of greenhouse gases (GHG) on the earth. In light of this, the current study employs the following EKC standard to investigate the impact of transport energy use and FDI on the environmental condition of ASEAN countries.

$$CO_{2it} = \beta_o + \beta_1 Y_{it} + \beta_2 Y_{it}^2 + \beta_3 TEC_{it} + \beta_4 FDI_{it} + e_{it} \quad (1)$$

where CO_2 is the per capita carbon emission, *TEC* is total energy consumption in the transport sector, *Y* stands for the real per capita GDP, Y^2 stands for a square of per capita, *FDI* is the inflow of foreign direct investment, and *e* is the error term supposed to be white noise. Moreover, *i* represents identities (countries), and *t* stands for time. The EKC would hold if β_1 were positive and significant and β_2 were negative and significant. The expected sign of β_3 should be positive, while for β_4 and β_5 it is uncertain, and can be positive as well as negative.

Data

The current study aims at analyzing the impact of transportation, economic growth, and FDI on the degradation of the environment in ASEAN nations. The study therefore employs real GDP per capita, energy used in transportation (kg of oil equivalent per capita), and FDI over the period 1980–2019. The panel of the ASEAN countries is made up of Thailand, the Philippines, Indonesia, Malaysia, and Singapore. The data is taken from the world development indicator (WDI, 2020). To compute per capita GDP and FDI in real terms, the GDP deflator (200 = 100) is employed. Moreover, logarithmic transformation is used for all the study variables to ensure immobility in the matrix of variance-covariance (Fatai et al., 2004). Figure 1 provides a flow chart of the analysis.

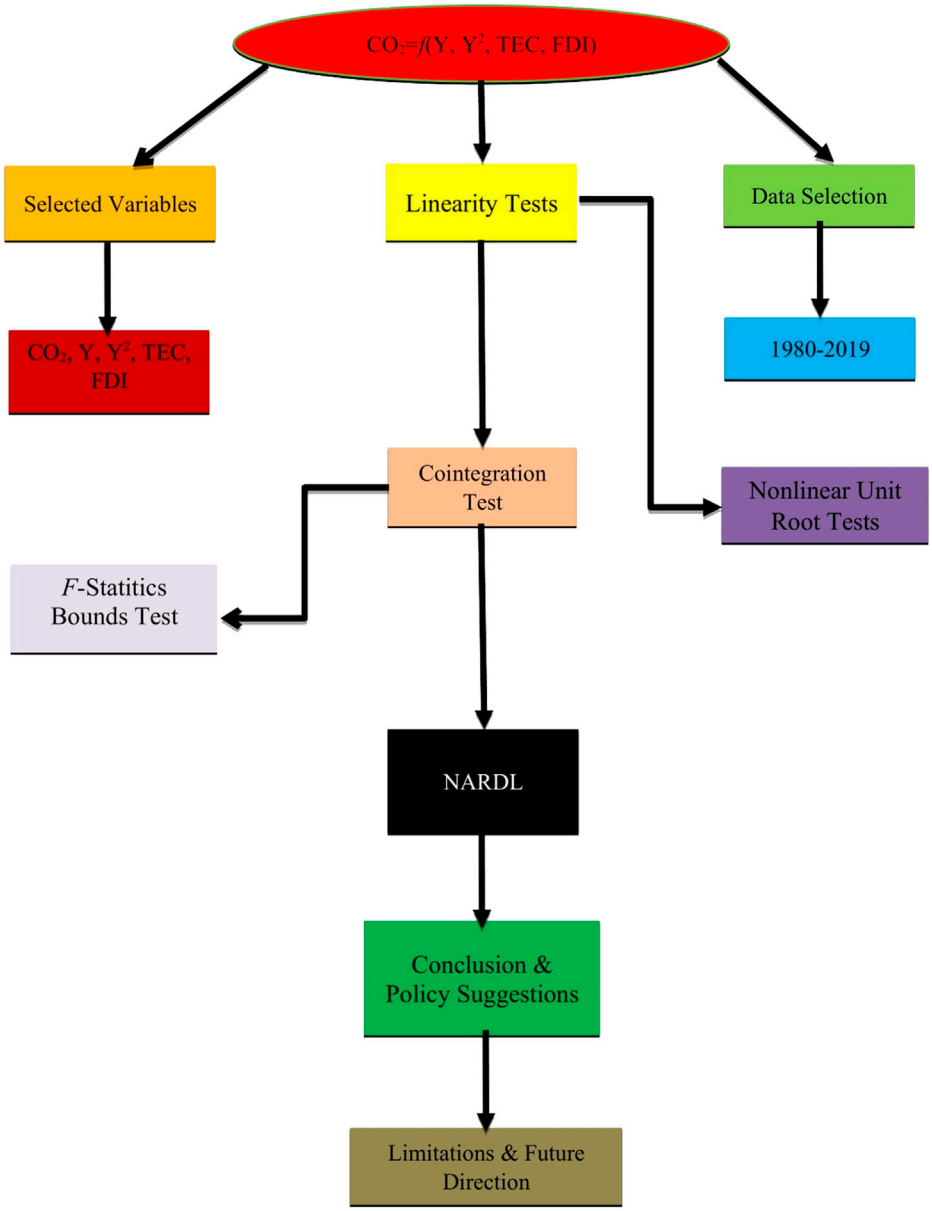

FIGURE 1
Flow diagram of the analysis.

Method of analysis

Instead of following sudden economic shocks, time-series data, especially environmental data, follows gradual change. The current study therefore uses the nonlinear auto regressive distributive lag (NARDL) developed by Kruse (2011). This test is an advanced version of the nonlinear stationary test of Kapetanios et al. (2003). Moreover, the main benefit of using time-series nonlinear ARDL is that it allows incorporation of the asymmetrical effects of negative and positive changes of independent variables on the dependent variable. Also, NARDL is comprehensive and simple enough to allow any kind of asymmetry moving from the short-run to the long-run.

Under this scheme, the general specification of Eq. 1 is represented as follows:

$$y_t = \gamma^+ V_t^+ + \gamma^- V_t^- + \varepsilon_t \quad (2)$$

where, γ^+ and γ^- are long-run parameters, and Vt is the vector representing several explanatory variables, which are shown in Eq. 3:

$$V_t = V_0 + V_t^+ + V_t^- \quad (3)$$

Here, V_t^+ and V_t^- are the positive and negative partial sums represented in Eqs 4 and 5:

$$V_t^+ \sum_{t=1}^{t} \Delta V_j^+ = \sum_{t=1}^{t} \max(\Delta V_i, 0) \quad (4)$$

$$V_t^- \sum_{t=1}^{t} \Delta V_j^- = \sum_{t=1}^{t} \min(\Delta V_i, 0) \quad (5)$$

The framework of non-linear and linear ARDL follows a similar procedure as that recommended by Pesaran et al. (2001). Accordingly, the null hypothesis $\rho = \varphi^+ = \varphi^- = 0$ is tested in the estimation of Eq. 7. In addition, the Wald test is conducted in nonlinear ARDL for estimating the long-run and short-run coefficients by $\varphi^+ = \varphi^-$ and $\mu^+ = \mu^-$, respectively. Furthermore, the impact of the increasing dynamic multiplier on the endogenous variable *yt*, represented by $V^+$and V^-, is expressed in Eq. 6:

$$m_k^+ = \sum_{i=0}^{k} \frac{\partial y_{t+i}}{\partial V_t^+}, \; m_k^- = \sum_{i=0}^{k} \frac{\partial y_{t+i}}{\partial V_t^-} k = 0, 1, 2 \quad (6)$$

where, $k \to \infty$, the $m_k^- \to \alpha^-$, and $m_k^+ \to \alpha^+$, and the long-run asymmetric $\gamma^+$and γ^- are already calculated and employed as follows:

$$\alpha^+ = \frac{-\varnothing^+}{\rho}, \; \alpha^- = \frac{-\varnothing^-}{\rho} \quad (7)$$

Results and discussion

The nonlinear ARDL empirical analysis starts with a linearity test of all the study variables included in the EKC model. Afterward, the unit root tests of Kruse (2011) and Kapetanios et al. (2003) are employed to observe the unit root existence in the time-series variables. Finally, the short-run and the long-run parameters are estimated and presented after establishing the cointegration relationship.

Linearity test

The linearity is been conducted using the approach of Harvey et al. (2008). According to the findings, the null hypothesis: variables are linear and are rejected for all four variables in selected ASEAN countries (see Table 2).

Nonlinear unit root tests

As this study analyzes 38 years of data, there is every chance that variables may not be stationary. The empirical analysis, therefore, proceeds by inspecting the stationary properties of the data. The outcome of both the stationary statistics reveals that the series are not stationary at the same level, and became stationary after differing (see Table 3).

TABLE 4 Bound test results.

Null hypothesis: No cointegration exists

Test Statistic	Value	*K*
F-statistic (Malaysia)	5.074	4
F-statistic (Indonesia)	6.229	4
F-statistic (Singapore)	4.961	4
F-statistic (Thailand)	6.041	4
F-statistic (Philippines)	6.111	4
Critical Bound Values		
Significance Levels	I_0 Lower bound	I_1 Upper bound
10%	2.11	3.01
5%	2.41	3.40
2.5%	2.69	3.80
1%	3.10	4.21

Bound test results

The findings of the bound test of cointegration are shown in Table 4. The results reveal that the calculated values of the *F*-statistic are higher than those of the corresponding I_1 bound at various permissible significance levels. Therefore, the test hypothesis of the absence of cointegration is rejected at all permissible levels of significance. This proves that a long-run relationship exists (cointegration) among the series combined in the EKC model for selected ASEAN countries.

The short-run and long-run coefficients

The short-run nonlinear ARDL results are given in Table 5. The results reveal that increased consumption of transport energy (TEC^+) increases CO_2 emissions, while decreased consumption of transport energy (TEC^-) has an insignificant effect on CO_2 emissions in Malaysia, Thailand, and the Philippines. In Indonesia and Singapore, increasing use of transport energy positively impacts CO_2 emissions, while decreasing use of transport energy does so negatively, as the coefficients are significant for both TEC^+ and TEC^-.

The long-run NARDL coefficients are presented in Table 6. According to these findings, FDI and energy consumption in transportation are the vital determining factors in the carbon emissions in these ASEAN nations. The results do not support the existence of EKC for the selected ASEAN economies except Singapore, however. These conclusions are similar to those of Gill et al. (2018a), who claimed that EKC for CO_2 emission does not exist in developing countries. Only advanced countries have reached the stage of economic development

TABLE 5 Short-run coefficients of NARDL.

Variables	*F*-statistic	Prob
Short-Run Coefficients for Malaysia		
Y_t	6.817	0.042
Y_t^2	−5.998	0.051
FDI	5.256	0.063
TEC^+	6.148	0.049
TEC^-	2.223	0.184
Short-Run Coefficients for Indonesia		
Y_t	5.124	0.069
Y_t^2	−6.047	0.050
FDI	5.310	0.059
TEC^+	5.999	0.050
TEC^-	7.013	0.039
Short-Run Coefficients for Singapore		
Y_t	2.311	0.190
Y_t^2	7.004	0.040
FDI	4.111	0.092
TEC^+	6.852	0.042
TEC^-	6.001	0.050
Short-Run Coefficients for Thailand		
Y_t	3.118	0.142
Y_t^2	6.898	0.041
FDI	3.550	0.126
TEC^+	7.257	0.034
TEC^-	1.168	0.250
Short-Run Coefficients for the Philippines		
Y_t	5.210	0.061
Y_t^2	−5.309	0.059
FDI	3.256	0.133
TEC^+	8.008	0.021
TEC^-	2.109	0.210

TABLE 6 Long-run coefficients of NARDL.

Variables	Coefficients	*t*-statistic	*Prob*
Long-Run Coefficients for Malaysia			
Y_t	0.310	6.456	0.001
Y_t^2	0.003	5.257	0.004
FDI	0.001	1.425	0.407
TEC^+	0.313	7.981	0.000
TEC^-	−0.015	−2.326	0.072
Long-Run Coefficients for Indonesia			
Y_t	0.782	4.449	0.011
Y_t^2	0.056	4.307	0.012
FDI	0.198	3.925	0.026
TEC^+	0.492	8.770	0.000
TEC^-	−0.021	−3.631	0.029
Long-Run Coefficients for Singapore			
Y_t	0.451	7.007	0.000
Y_t^2	−0.001	−7.226	0.000
FDI	−0.290	−4.254	0.013
TEC^+	0.201	4.456	0.010
TEC^-	−0.066	−5.005	0.008
Long-Run Coefficients for Thailand			
Y_t	0.651	7.056	0.000
Y_t^2	0.003	4.111	0.019
FDI	0.231	4.925	0.009
TEC^+	0.612	8.590	0.000
TEC^-	−0.010	−1.982	0.109
Long-Run Coefficients for the Philippines			
Y_t	0.410	6.098	0.003
Y_t^2	0.034	6.877	0.001
FDI	0.035	1.925	0.101
TEC^+	0.482	7.540	0.000
TEC^-	−0.126	−3.666	0.028

where the EKC for carbon emissions starts turning. The results also support the claim of Stern (2004), that developing economies are on the augmenting side of the EKC, whereas developed nations are on the falling side of the curve. In the present context, Singapore is an advanced economy, Malaysia a middle-income country, while Indonesia, Thailand and the Philippines have the status of developing economies. The results imply that further economic growth in Malaysia, Indonesia, Thailand, and the Philippines will be accompanied by more CO_2 emissions unless necessary measures are taken.

The long-run elasticities in energy consumption for transportation in relation to CO_2 emissions are positively significant in all selected ASEAN countries. However, the magnitude of the coefficients vary from Thailand to Singapore, i.e., 0.6124 for Thailand, 0.4923 for Indonesia, 0.4823 for the Philippines, 0.313 for Malaysia, and 0.2013 for Singapore. The weak elasticities in Malaysia and Singapore indicate the better quality of transport vehicles and greater use of the public transport systems there. These results are similar to the conclusion of Haddad et al. (2018), Liu et al. (2018), and Ozturk and Acaravci (2016), who claim a significant

impact of transportation on CO_2 emissions. Moreover, the asymmetrical NARDL effects indicate that decreasing transport energy consumption significantly decreases CO_2 emissions in five ASEAN countries.

Similarly, the effects of FDI on carbon emissions in designated ASEAN countries are also positive, except for Singapore. The negative coefficient indicates that the Singaporean economy is mature enough to attract quality FDI in the services sector. The economy of Singapore is at a stage where advanced technologies mitigate the effect of growth and FDI on environmental degradation. To support this argument, many international corporations engage their resources through FDI, which may bring innovative techniques and will tend to disseminate clean technologies that enhance environmental performance. However, the rest of the ASEAN economies are lagging behind at this stage. The coefficient of FDI is 0.2311 in Thailand, 0.1978 in Indonesia, and 0.0345 in the Philippines, while it is insignificant in Malaysia. The positive effect demonstrates that the progression of FDI from advanced nations to developing regions is mainly capitalized on manufacturing, mining, and electricity, all of which undoubtedly increase environmental contamination in developing nations (Kirikkaleli et al., 2022). These findings are consistent with Awan et al., (2022b). Interestingly, the FDI effect on the environment is smaller than that of energy use in the transport sector. This suggests that improving transport technologies would effectively mitigate environmental issues in ASEAN countries.

Conclusion and recommendations

The basic intention of this work was to scrutinize the dynamic association between economic growth, road transportation energy consumption, FDI, and CO_2 emissions for five selected ASEAN economies. The empirical results reveal a long-run cointegration between CO_2 emission and its determining factors: income growth, transport energy consumption, and FDI inflows. The EKC relationship between CO_2 emission and economic growth exists only in Singapore. These results imply that Singapore has reached a point of economic development where care about the environment becomes a part of economic growth. The results also highlight the fact that, despite Singapore having been the main destination for FDI of the countries examined, such investment is mainly concentrated in the services sector, where it has less room to influence carbon emissions. Similarly, energy consumption in transportation in Singapore has a very meager impact on CO_2 emissions, mainly due to an efficient public transport system and good quality vehicles.

For the other four ASEAN nations, results do not support the EKC relationship between economic growth and the environment. This implies that these nations are in the early phases of economic development, where further income growth degrades the environment, and that they should therefore pursue cautious growth policies. The results also reveal that transportation has more impact on the environment than FDI. Policies targeting emission reduction in ASEAN countries should thus concentrate on types of FDI inflows and the type of fuel consumed in transportation. Energy-efficient vehicles, greater public transport use, and encouragement of carpooling will reduce the energy intensity in the transport sector. We also recommend reinventing mobility models by redesigning cities in such a way that mobility is minimized. Fossil fuel prices should reflect the environmental cost of burning this fuel, especially in the transport sector. The empirical findings show that ASEAN nations urgently need to implement extended, well-organized strategies in aspects of their sustainable development initiatives, so as to encourage eco-friendly, clean, and energy-efficient foreign funding in the industrial field. ASEAN economies should look at improving their infrastructure and regulatory systems in pursuit of low-emission energy, and seek more efficient energy mechanisms to encourage emission-free funding. Ecological damage can also be reduced by boosting the usage of renewable energy sources. To achieve this, companies should be urged to enforce eco-friendly practices, modern import techniques, and remodel and reshape established machinery to cleaner capital in order to safeguard environmental excellence. In sum, FDI has a greater capacity for developing executive ecological exercises when functioning from the perspective of sustainable development.

Policymakers should take note of the conclusions of this document. Exceptional effort will be required to find strategies that enhance investment in renewable energy sources and that substantially safeguard the environment. The current study is far from perfect, as there are a number of constraining factors. Foreign direct investment and the transport energy consumption are not the only factors influencing carbon emissions, for example. Another limitation of this empirical investigation is lack of data. Similarly, future studies may expand on this investigation by considering the impact of export quality, remittance outflows, natural resources, trade, and human capital on various energy and environmental measures (e.g., the ecological footprint) for more consistent and effective results, as well as for their useful and pragmatic

ramifications at both city and state levels in this geographical area.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: https://databank.worldbank.org/source/world-development-indicators.

Author contributions

All authors listed made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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