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The Impact of Trade Cooperation with China, Financial Development, FDI Flows, and Economic Growth on Environmental Degradation in ASEAN-5 Economies

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ABSTRACT

Through the widespread implementation of green development, the Chinese government hopes to achieve shared prosperity while ensuring sustainable development. For all countries participating in the Belt and Road Initiative, sustainable development remains a priority. The pooled mean group (PMG) technique was employed in the present study to investigate the factors impacting environmental cleaning, economic growth, and trade cooperation between China and ASEAN-5 economies between 1992 and 2020. The empirical evidence suggests that trade cooperation with China is advantageous for environmental cleaning and economic sustainability in the explored economies. According to the results of a Sasabuchi-Lind-Mehlum (SLM) test, the environmental Kuznets curve (EKC) hypothesis applies to all ASEAN-5 economies except the Philippines. The causality test findings indicated that trade cooperation with China played a decisive role in influencing the environmental and economic conditions of ASEAN-5. The empirical results have led the study's researchers to propose policy suggestions for ASEAN-5 economies. The economies are recommended to adopt a cooperation and self-development mode that balances economic growth and environmental cleaning while pursuing the ultimate mission of the "Green Belt and Road Initiative".

Keywords: Trade, Belt Road, Economic Growth, EKC Hypothesis
JEL Classifications: C23, H30, O40

1. INTRODUCTION

As globalisation strengthens international trade relationships, the ASEAN-5 economies, comprising Singapore, Malaysia, Indonesia, Thailand, and the Philippines, have attained considerable economic growth and gradually emerged as prominent trading partners globally. Nevertheless, the rapid development of these economies has also resulted in environmental degradation. Most countries in Southeast Asia are categorised as developing economies. Unfortunately, the region has become the world's third-largest emitter because of its heavy reliance on fossil fuels and low investment in energy technology (Ahmed et al. 2017). As illustrated in Figure 1, environmental degradation results in serious economic losses (World Bank, 2024). With even graver consequences and the worsening of global warming caused by the greenhouse effect, the Philippines and Indonesia face an elevated risk of submerging and flooding due to rising sea levels in recent decades (Lean and Smyth, 2010). The worsening impact of global warming has raised the question of how to minimise the harmful environmental consequences of rapid economic growth to receive significant attention from relevant stakeholders.

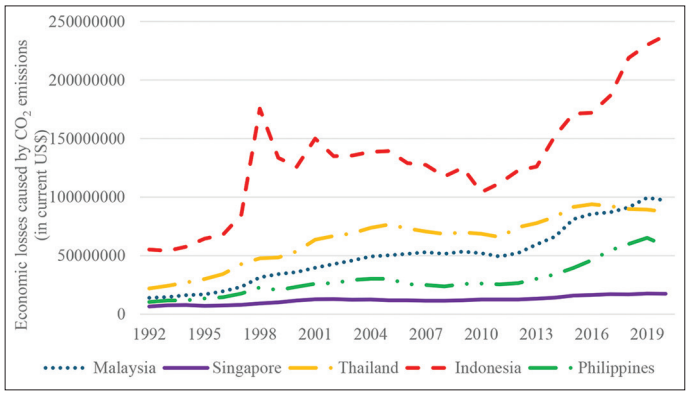
The Chinese government put forward the Belt and Road Initiative (BRI) in 2013. This national-level initiative aimed to improve

infrastructure through active trade cooperation with China, enabling every country involved to achieve shared economic prosperity (Sun et al., 2019). By acknowledging its responsibility for reducing climate change, the Chinese government has ensured that the development of the BRI conforms to the Sustainable Development Goals [SDGs] 2030 outlined by the United Nations (Dong et al., 2018). As illustrated in Figure 2, the volume of bilateral trade between the ASEAN-5 economies and China has continued to increase in the last few decades (WITS, 2024). At the same time, becoming a member state of the BRI has strengthened such cooperation.

The issue of environmental pollution in Southeast Asian countries because of their rapid economic growth has been widely discussed in academia in recent years. Nevertheless, the lack of studies that explored the impact of ASEAN-5's trading partners on their environmental situations highlights insufficient research on the topic. While the economic relations between ASEAN-5 economies and their trading partners continue to strengthen, the correlation between economic growth, trade cooperation, and environmental cleaning lacks comprehensive analysis. Thus, the impact of environmental cleaning on their development and trade cooperation with other economies should be comprehensively discussed. The current study is intended to fill the gap mentioned above and explore the effect of trade cooperation with China on environmental cleaning and economic development in ASEAN-5 economies.

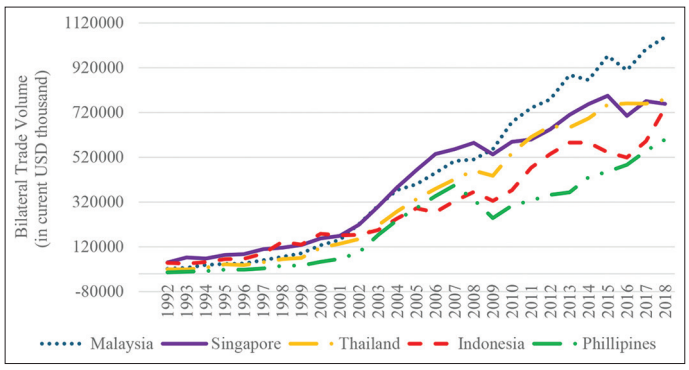
The following is the organisation of the paper: The relevant literature is summarised in the next section. The definition of the variables used and the introduction for the data, models, and methodology are available in Section 3. The subsequent section divulges and compares the empirical results with previous research. In the final section, the study will conclude the policy suggestion according to the empirical results observed in the process of practical operation.

Figure 1: Economic losses caused by CO_2 emissions



Source: World Bank (2024)

Figure 2: Trends in Bilateral Trade Between ASEAN-5 economies and China



Source: WITS (2024)

2. LITERATURE REVIEW

The following discussion focuses on relevant previous research by summarising the related relevant literature in the order of the study's explored variables.

2.1. Impact of Trade Cooperation on Environmental Degradation

In the exploration of developing nations, to prove the presence of the pollution haven hypothesis (PHH) due to the relatively lax environmental standards, scholars typically examine how trade cooperation affects environmental pollution. The transfer of high-pollution work from developed economies to developing economies continues to occur, eventually leading to environmental degradation (Cole, 2004). Numerous studies have explored the impact of trade cooperation in developing economies on environmental cleaning (Musah et al., 2021; Khan et al., 2022) and found evidence supporting PHH. In the investigation targeted specifically on the ASEAN region, evidence of the PHH has been found in most economies since trade cooperation positively impacts environmental pollution (Ahmed et al., 2017). One study investigated 112 economies with varying development levels and discovered that trade cooperation was advantageous for high-income economies but caused severe environmental issues in lower-income countries (Gulistan et al., 2020). This phenomenon was also verified by a study undertaken in the European Union (Destek et al., 2018), which indicated that trade cooperation promoted environmental cleaning in developed economies. The findings of existing studies support the past empirical finding that environmental cleaning can be achieved naturally if trade cooperation between economies reaches a certain level (Wang et al., 2023).

A study focusing on Azerbaijan revealed that trade cooperation could significantly affect environmental degradation (Mukhtarov et al., 2023). Additionally, similar findings were also obtained in a South African study (Udeagha and Breitenbach, 2023). Nevertheless, pollution caused by trade cooperation is not exclusive to developing economies. Evidence indicating that trade cooperation harms the environment has also been found in France and Greece (Omri and Saadaoui, 2023; Işik et al., 2017), as well as other newly industrialised economies, including China, Malaysia, and Thailand (Zhang et al., 2017). Most of the investigations mentioned above chose trade openness as the trade cooperation variable to analyse its impact on environmental cleaning but overlooked considering the mirror trade effects. As per the researchers' knowledge, no studies have chosen an individual bilateral trading partner to conduct such an investigation to date.

2.2. Impact of Economic Growth on Environmental Degradation

Scholars have typically examined whether the EKC hypothesis holds true in their research settings when investigating how

economic growth affects environmental degradation. As per this hypothesis, countries in the initial development stage are likely to experience increased environmental degradation due to their emphasis on economic growth. Scholars have extensively discussed this phenomenon and arrived at various conclusions. In an early survey, scholars investigating the EKC hypothesis in five European Union member countries suggested that continuous economic growth was detrimental to environmental cleaning (Balsalobre-Lorente et al., 2018). Similar findings were also reported in a survey on Sub-Saharan economies, which failed to detect the EKC (Abid, 2016). The conventional assumption highlights that if long-term factors (square term of GDP) are not accounted for if long-term factors (square term of GDP) are not accounted for, economic growth can negatively impact the environment. Nevertheless, evidence diverging from this assumption was found in an investigation that included Brazil, Russia, India, China, and South Africa (BRICS), Mexico, Indonesia, Nigeria, and Turkey (MINT), and America France, Britain, Germany, Japan, Italy, and Canada the G7 economies (Ofori et al., 2023). The EKC hypothesis is not always valid in developed economies, as all these studies have noted, but it may hold true in developing economies. Therefore, there is still uncertainty regarding the relationship between economic growth and environmental cleaning.

A series of previous investigations undertaken in ASEAN-5 economies empirically explored the EKC hypothesis. Nevertheless, their results were mixed. Saboori et al. (2012) observed an inverted U-shaped relationship between carbon emissions and economic growth in Malaysia, providing evidence in support of the EKC hypothesis. In another study carried out in Malaysia, Begum et al. (2015) identified a U-shaped relationship, which did not corroborate the EKC hypothesis. In Singapore's case, Mehmood (2021) confirmed the presence of the hypothesis due to the significant negative and positive constant item and square item coefficients of economic growth. Based on the observed inverted U-shaped relationship, a survey conducted by Ike et al. (2020) confirmed the EKC hypothesis in Thailand. Nevertheless, Lean and Smyth (2010) failed to obtain conclusive results regarding the EKC hypothesis in Singapore. In Indonesia, Massagony and Budiono (2023) found a U-shaped relationship, while Alam et al. (2016) discovered an inverted U-shaped relationship. Through observation of the Philippines, Saboori and Sulaiman (2013) identified a U-shaped relationship, rejecting the EKC hypothesis. In contrast, Lean and Smyth (2010) observed an inverted U-shaped relationship, which supported the EKC hypothesis. Similarly, in the ASEAN-5 economies, evidence indicating the presence of both an inverted U-shaped relationship (Munir et al., 2020) and a U-shaped relationship (Chandran and Tang, 2013) has also been found.

2.3. Impact of Financial Factors Related to Environmental Degradation

Financial factors may also significantly affect environmental degradation. The study summarises the impact exerted on environmental cleaning due to financial development and FDI. According to Ullah et al. (2023), continuous financial development can meet societal needs for financial support but negatively impact the environment as social purchasing power increases. Their investigation of 14 financially developed economies clearly indicated that the ecological footprint of these economies has been influenced by financial development. According to a study undertaken in India, economic growth and financial development negatively impacted environmental cleaning (Sethi et al., 2020). A recent survey revealed that by increasing carbon emissions in BRICS economies, financial development has been detrimental to environmental cleaning (Wang et al., 2024). Additionally, scholars have also observed that financial stability promotes environmental cleaning in South Asian economies (Nasreen et al., 2017).

The impact of FDI on environmental cleaning should also be considered. Scholars have indicated that this variable can be utilised to test PHH in each research setting (Chandran and Tang, 2013). If the investigation reveals that the FDI was detrimental to environmental cleaning, the evidence of PHH can be found. A study conducted in 59 member states of the BRI revealed that while economic growth harms the environment, financial development and FDI positively contribute to environmental cleanliness (Saud et al., 2019).

2.4. Determinants of Economic Growth and Trade Cooperation

As this study's main concern expands, the factors affecting economic sustainability and trade cooperation with China should also be considered. The work conducted by Magazzino et al. (2021) revealed that financial development must be considered when exploring its influence on economic growth, as their investigation into 114 economies in the agricultural sector revealed that financial development, productivity, and output interact with one another. By focusing on South Asian economies, Ahmed et al. (2022) discovered that financial development positively impacts green economic growth based on traditional gross domestic product (GDP) and stresses environmental protection. A previous survey stated that FDI attracted by high-speed economic growth can significantly impact international trade, which can ultimately promote economic growth (Wang et al., 2016).

In fact, Magazzino and Mele (2022) emphasised the importance of FDI and believed that it can be treated as an essential decisive factor in the economic integration process since it promotes a stable relationship among the economies. While exploring the relationship between FDI and economic growth, the study discovered that the neutrality hypothesis exists in Malta. Therefore, the roles of FDI in environmental cleaning, economic growth, and trade cooperation are worth considering collectively. In addition, trade cooperation promotes economic development, as evidence indicating that economic growth is beneficial to trade cooperation has also been found in the ASEAN context (Shen, 2023). One study found that relevant laws and regulations enabled cities with high levels of technological development to enhance the spillover effect through import trade, leading to better environmental cleaning (Shang et al., 2022). Based on this result, reverse thinking about whether the changing environmental and economic conditions will significantly influence trade cooperation is necessary. By utilising a dynamic common correlated effects model, Khan et al. (2020) found that environmental factors significantly affected trade cooperation in Nordic economies. In a recent study, Chen et al.

(2023) discovered that environmental pollution was detrimental to trade cooperation in agricultural exports with China.

2.5. Related Studies on Environment Degradation from ASEAN Perspectives

Since the study's primary aim is to explore the determinants affecting environmental cleaning in ASEAN-5 economies, this section will streamline the literature selection and summarise the selected literature relating to environmental conditions in ASEAN. By applying the Dynamic Ordinary Least Square (DOLS), Lean and Smyth (2010) explored the relationship between economic growth and carbon emissions in ASEAN-5 economies. Through observation in the ASEAN-5, the authors discovered that the EKC hypothesis was present. Nevertheless, the EKC only existed in the Philippines when individual investigation was conducted. Nevertheless, Chandran and Tang (2013) claimed that two of the ASEAN-5 economies, Thailand and Malaysia, did not conform to the EKC hypothesis. Saboori and Sulaiman (2013) discovered that among all ASEAN-5 economies, only Singapore and Thailand fit the EKC hypothesis through the adoption of the autoregressive distributed lag (ARDL) technique. In addition, by applying fully modifying ordinary least squares (FMOLS), Ahmed et al. (2017) found that economic growth and trade cooperation significantly affected the ASEAN economies from 1985 to 2015. Based on the findings of Driscoll-Kraay standard error regressions, Munir et al. (2020) stated that, in ASEAN-5 economies, the EKC hypothesis was present.

In exploring the relationship between economic growth and carbon emissions in Malaysia, Saboori et al. (2012) adopted the ARDL technique and confirmed the existence of the EKC hypothesis. Nevertheless, in exploring the environmental condition in Malaysia based on the results of the DOLS, ARDL, and SLM U-test, Begum et al. (2015) observed a U-shaped relationship between carbon emissions and economic growth. They rejected the presence of the EKC hypothesis. In exploring the environment in Singapore, Mehmood (2021) adopted the ARDL technique to reveal the existence of the EKC hypothesis. Additionally, evidence suggests that globalisation could significantly influence environmental degradation. Ike et al. (2020) claimed that the EKC hypothesis existed in Thailand based on the results of the DOLS technique. They also discovered that fiscal policy could have a significant influence on environmental degradation. To explore the relationship between economic growth and Indonesia, Massagony and Budionio (2023) applied the ARDL technique. The empirical findings showed that the EKC hypothesis was not present. To conclude, in the current stage, all the selected literature was found to specifically focus on the determinants affecting environmental cleaning and the existence of the EKC.

3. METHODOLOGY

The literature reviewed above provides theoretical support for the study's empirical analysis. Data collection methods and the econometric model, namely the balanced panel data covering the ASEAN-5 economies (Malaysia, Thailand, Singapore, Indonesia, and the Philippines) from 1992 to 2020, are presented in this section. This study represents the initial effort to investigate the influence of cooperation with other countries on economies' environmental cleaning and national development. The variable reflecting trade cooperation should be objective and impartial. By following the work of Tee et al. (2020), trade cooperation is measured using mirror data on the total bilateral trade volume with ASEAN-5 economies from China's perspective in this study. This method effectively avoids the issue of significant differences in trade volume reported due to differences in customs regulations between countries. The variable trade cooperation (TR) is measured in thousands of current US dollars. All the relevant data were acquired from the database of World Integrated Trade Solution (WITS) (2024).

The measure of economic growth is GDP, expressed per capita in current US dollars, while financial development (FD) is represented by the percentage of GDP in domestic credit provided to the private sector by banks. The FDI represents the total FDI inflow, measured in current US dollars. Carbon emissions are measured in metric tonnes per capita and reflected by CE. The definitions of the variables and data sources are detailed in Table 1. All these variables were transformed to logarithmic form for the empirical analysis.

3.1. Econometrics Modelling

The study's primary aim is to investigate the impact of trade cooperation with China on environmental cleaning in ASEAN-5 economies, with theoretical support gained from the work of Cole (2004). Testing the PHH in the context of ASEAN-5 economies' trade cooperation with China is crucial. According to the work of Saboori et al. (2012), another research objective is to verify whether the EKC hypothesis holds true. To achieve this objective, the model incorporates both the constant and squared terms of GDP. According to the opinion provided by Ullah et al. (2023), which indicates that changes in social purchasing power due to financial development ultimately influence the environment,

Table 1: Variable descriptions and data sources

Variable name	Variable symbol	Variable description	Data source
Carbon emissions	CE	CO_2 emissions (metric tonnes per capita)	World Bank (2024)
Bilateral trade volume	TR	Total bilateral trade volume between ASEAN-5 and China measured in thousand current US dollars	World Integrated Trade Solution (2024)
Economic sustainability	GDP	GDP per capita measured in current US dollars	World Bank (2024)
Financial development	FD	Domestic credit to the private sector by banks in percentage of GDP in current US dollars	World Bank (2024)
Foreign direct investment	FDI	Net inflows of foreign direct investment. Measured in current US dollars	World Bank (2024)

WDI: World development indicators, WITS: World integrated trade solution

the FD must be measured. Inspired by the opinion proposed by Magazzino and Mele (2022) that FDI is an essential aspect of international economic integration, the model includes FDI when examining the impact of economic behaviour on environmental sustainability. By referencing the model established by Ansari and Khan (2021) and making the appropriate adjustment, the impact of trade cooperation with China and economic sustainability on environmental cleaning in ASEAN-5 economies were examined in this study, which can be expressed as shown in the equation below:

$$CE_{it} = f(TR_{it}, GDP_{it}, FD_{it}, FDI_{it}) \quad (1)$$

Eq. (1) is the function of Model 1, which is this study's prioritised focus. The model's dependent variable is CE, which refers to carbon emissions. The primary objective of setting Model 1 is to determine whether the study's variables significantly impact environmental cleaning in the ASEAN-5 economies. The independent variables include TR, GDP, FD, and FDI. After transforming into the logarithmic form, the study utilised the square term of economic growth, labelled as GDP squared in the model, to test the EKC hypothesis. The model can be represented as follows:

$$CE_{it} = \alpha_0 + \alpha_1 TR_{it} + \alpha_2 GDP_{it} + \alpha_3 GDP_{it}^2 + \alpha_4 FD_{it} + \alpha_5 FDI_{it} + \varepsilon_{it} \quad (2)$$

Rotating the dependent variables using this model allows for the natural elaboration of other functions that explore the determinants of GDP and TR. These expansion models align with the works of Shen (2023), which focus on studies associated with economic cooperation in the ASEAN region. The following expectations related to the influence of the independent variables on the dependent variables were formed based on the literature review:

$$CE_{it} = f\left(\overset{-}{TR_{it}}, \overset{-/+}{GDP_{it}}, \overset{-}{GDP_{it}^2}, \overset{+}{FD_{it}}, \overset{+}{FDI_{it}}\right) \quad (3)$$

$$GDP_{it} = f\left(\overset{-}{CE_{it}}, \overset{+}{TR_{it}}, \overset{+}{FD_{it}}, \overset{+}{FDI_{it}}\right) \quad (4)$$

$$TR_{it} = f\left(\overset{+}{CE_{it}}, \overset{+}{GDP_{it}}, \overset{+}{FD_{it}}, \overset{-/+}{FDI_{it}}\right) \quad (5)$$

These expected relationships lead to the development of research hypotheses that align with the research questions and objectives. Before the formal empirical analysis was undertaken in this study, all the expected signs were estimated using previous empirical findings. The second research hypothesis suggests that the EKC hypothesis holds true in ASEAN-5 economies. Based on functions (3), (4), and (5), the study generates mathematical equations as expressed below:

$$CE_{it} = \alpha_0 + \alpha_1 TR_{it} + \alpha_2 GDP_{it} + \alpha_3 GDP_{it}^2 + \alpha_4 FD_{it} + \alpha_5 FDI_{it} + \varepsilon_{it} \quad (6)$$

$$GDP_{it} = \alpha_0 + \alpha_1 CE_{it} + \alpha_2 TR_{it} + \alpha_3 FD_{it} + \alpha_4 FDI_{it} + \varepsilon_{it}) \quad (7)$$

$$TR_{it} = \alpha_0 + \alpha_1 CE_{it} + \alpha_2 GDP_{it} + \alpha_3 FD_{it} + \alpha_4 FDI_{it} + \varepsilon_{it} \quad (8)$$

Eq. (6), (7), and (8) relate to the factors that are hypothesised to significantly affect environmental cleaning, economic growth, and trade cooperation with China in ASEAN-5 economies. The empirical study aimed to determine whether significant quantitative relationships exist between the independent and dependent variables.

3.2. Diagnostic Tests

The Shapiro-Wilk (SW) test proposed by Shapiro and Wilk (1965) and the Shapiro-Francia (SF) by Shapiro and Francia (1972) test was employed as normality tests to explore whether the dataset follows a normal distribution in the preliminary analysis. If the null hypothesis of a normal distribution for the datasets is rejected, referencing the work of Olayungbo and Quadri (2019), the datasets may exhibit heterogeneity and cross-sectional dependence. In such cases, to validate the reliability of the subsequent regression results, researchers need to perform a series of diagnostic tests. Following their logic process, a test of cross-sectional dependence was adopted (Pesaran, 2004). The estimation technique can be summarised as follows:

$$CD_{Pesaran} = \sqrt{\frac{2T}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} p_{ij} \quad (9)$$

In this technique, within this cross-sectional dependence test, p_{ij} refers to the correlation coefficients from the residual term of the regression. Once the cross-sectional dependence rejects the null hypothesis, the findings indicate that no cross-sectional dependence is present across the countries' datasets. If the variables' datasets are cross-sectional dependent, the corresponding panel unit root test and panel cointegration test can be utilised to decrease the estimation errors.

Besides the cross-sectional dependence test, to determine whether the models are homogeneous or heterogeneous panels, a slope homogeneity test was employed (Pesaran and Yamagata, 2008). The stated test is as follows:

$$\tilde{\Delta} = \frac{1}{\sqrt{n}} \left(\frac{\sum_{i=1}^{N} \overline{d_i} - k_2}{\sqrt{2k_2}} \right) \quad (10)$$

$$\tilde{\Delta}_{adj} = \sqrt{N} \left(\frac{N^{-1} \sum_{i=1}^{N} \overline{d_i} - k_2}{\sqrt{Var(Z_i, T_i)}} \right) \quad (11)$$

If the null hypothesis is rejected, the findings confirm that the estimation is subject to heterogeneous conditions. The homogenous panel condition occurs if the null hypothesis is accepted. The heterogeneous unit root test suggested by following the work of Herwartz and Siedenburg (2008) was adopted in the present study due to the differing patterns of data series across all ASEAN countries. In this unit root test, cross-sectional dependence and heterogeneity detected in the panel are considered, which is shown as follows:

$$t_{HS} = \frac{\sum_{t=1}^{T} y'_{t-1} \Delta y_t}{\sqrt{\sum_{t=1}^{T} y'_{t-1} \hat{e}_t \hat{e}_t y_{t-1}}} \quad (12)$$

This method assumes that the unit root exists in the panel as the null hypothesis. Even if cross-sectional dependence and heterogeneity exist, rejecting the null hypothesis indicates that the datasets are stable and will prevent spurious regression. After conducting the panel unit root test, the study proceeded with a panel cointegration test.

3.3. Heterogeneous Panel Cointegration Test

As mentioned earlier, each of the ASEAN-5 economies varies widely in their national characteristics and development. Thus, using heterogeneous panels in the formal empirical analysis is necessary. The Westerlund panel cointegration test (Westerlund, 2007) was utilised in the study to identify whether long-term cointegration relationships exist among the variables and to ensure that the empirical results are accurate. Moreover, this method has also been used to capture the EKC condition by Munir et al. (2020) in ASEAN-5 economies. The heterogeneous cointegration model is described below:

$$\Delta y_{it} = \theta'_i d_t + \propto_i \left(y_{it-1} - \beta'_i x_{it-1} \right) + \sum_{j=1}^{mi} \propto_{ij} \Delta y_{it-j} + \sum_{j=1}^{mi} \gamma_{ij} \Delta x_{it-j} + \varepsilon_{it} \quad (13)$$

where,

$$G_t = \frac{1}{N} \sum_{i=1}^{N} \frac{\hat{\alpha}}{SE(\hat{\alpha}_i)} \quad (14)$$

$$G_a = \frac{1}{N} \sum_{i=1}^{N} \frac{T\hat{\alpha}}{\hat{\alpha}_{i(1)}} \quad (15)$$

$$P_t = \frac{\hat{\alpha}}{SE(\hat{\alpha})} \quad (16)$$

$$P_a = T\hat{\alpha} \quad (17)$$

The Westerlund heterogeneous cointegration test utilises G_a and G_t as group statistics and P_a and P_t as panel statistics. In the cointegration test, panel error correction is typically employed instead of the usual panel residual dynamics, and no common restriction factor exists. The null hypothesis of the panel test can be derived as H_0:α_j= 0 and H_1:α_j= $\alpha < 0$ for all individuals in the pooled data. Additionally, the group statistics measured do not account for error correction information. If any of the above four statistical values are significant at the designated level (P-value), the null hypothesis can be rejected. The outcome proved the existence of a long-run equilibrium among the variables.

3.4. The Pooled Mean Group (PMG) Estimation

After performing the cointegration test, the quantitative relationships between the independent and dependent variables were empirically analysed in the study. The PMG was selected in this study to estimate since the technique's superiority enables it to explore the short-run and long-run relationship (Pesaran et al., 1999). To confirm the presence of the EKC hypothesis in South Asian economies, Ozturk et al. (2024) also applied the PMG technique. The PMG estimates are derived as follows:

$$\Delta CE_{it} = \lambda_0 + \alpha_1 CE_{it-1} + a_2 TR_{it-1} + \alpha_3 GDP_{it-1} + \alpha_4 GDP^2_{it-1} + \alpha_5 FD_{it-1} + \alpha_6 FDI_{it-1} + \sum_{j=1}^{p} \beta_{it} \Delta CE_{i,t-j} + \sum_{j=0}^{q} \beta_{it} \Delta TR_{i,t-j} + \sum_{j=o}^{q} \beta_{ij} \Delta GDP_{i,t-j} + \sum_{j=o}^{q} \beta_{ij} \Delta GDP^2_{i,t-j} + \sum_{j=0}^{q} \beta_{it} \Delta FD_{i,t-j} + \sum_{j=0}^{q} \beta_{it} \Delta FDI_{i,t-j} + \gamma ECT_{t-1} + \varepsilon_{it} \quad (18)$$

$$\Delta GDP_{it} = \lambda_0 + \alpha_1 GDP_{it-1} + \alpha_2 CE_{it-1} + \alpha_3 TR_{it-1} + \alpha_4 FD_{it-1} + \alpha_5 FDI_{it-1} + \sum_{j=1}^{p} \beta_{it} \Delta GDP_{i,t-j} + \sum_{j=0}^{q} \beta_{it} \Delta CE_{i,t-j} + \sum_{j=0}^{q} \beta_{it} \Delta TR_{i,t-j} + \sum_{j=o}^{q} \beta_{ij} \Delta FD_{i,t-j} + \sum_{j=0}^{q} \beta_{ij} \Delta FDI_{i,t-j} + \gamma ECT_{t-1} + \varepsilon_{it} \quad (19)$$

$$\Delta TR_{it} = \lambda_0 + \alpha_1 TR_{it-1} + \alpha_2 CE_{it-1} + \alpha_3 GDP_{it-1} + \alpha_4 FD_{it-1} + \alpha_5 FDI_{it-1} + \sum_{j=1}^{p} \beta_{it} \Delta TR_{i,t-j} + \sum_{j=0}^{q} \beta_{it} \Delta CE_{i,t-j} + \sum_{j=0}^{q} \beta_{it} \Delta GDP_{i,t-j} + \sum_{j=o}^{q} \beta_{ij} \Delta FD_{i,t-j} + \sum_{j=0}^{q} \beta_{ij} \Delta FDI_{i,t-j} + \gamma ECT_{t-1} + \varepsilon_{it} \quad (20)$$

In these three models, α denotes the long-run coefficient, while β represents the short-run coefficient of the estimates. In the short-run coefficient, p is the maximum lag order of the dependent variables, whereas q is the maximum lag order of the independent variable. The error correction term (ECT_{t-1}) is crucial to this technique, and its coefficient must be negative and significant. If the error correction term is significant with the P-value, this outcome supports the alternative hypothesis of a long-run cointegration relationship.

3.5. Sasabuchi-Lind-Mehlum (SLM) Test

After using the findings of the PMG estimation to test the EKC hypothesis, the SLM test (Lind and Mehlum, 2010) was conducted in the study to strengthen its findings. This test allows for further exploration of the ASEAN-5 economies to validate whether the EKC hypothesis holds true in each of these countries. Presenting significant statistical values and the entire curve for the sample period is necessary to test the EKC rigorously. Ideally, to confirm the EKC hypothesis, the curve representing carbon emissions would gradually increase in the initial stage of the sample period and subsequently decline gradually towards the end of this period. The technique used to conduct this test is as follows:

$$CE_{it} = \alpha GDP_{it} + \beta GDP^2_{it} + \gamma V_{it} \quad (21)$$

In the SLM test, CE and GDP are the only variables that need to be considered. The null and alternative hypotheses are summarised below:

$$H_0: (\alpha + \beta 2 GDP_{min} \leq 0) \cup (\alpha + \beta 2 GDP_{max} \geq 0) \quad (22)$$

$$H_1: (\alpha + \beta 2 GDP_{min} > 0) \cup (\alpha + \beta 2 GDP_{max} < 0) \quad (23)$$

The minimum and maximum values of the GDP variable are GDP_{min} and GDP_{max}, as determined by the fundamental SLM equation. Based on the sign of the first-order derivative, this study aims to determine whether the inverted U-shape relates

to environmental conditions and economic development. If the P-value of the SLM test indicates significance, an inverted U-shape is present, and the EKC hypothesis can be assumed to hold true. In the ASEAN context, as observed by this study, only Begum et al. (2015) adopted the SLM U-shape test to explore the existence of EKC in Malaysia. With the aim of filling the gap, the study included both ASEAN-5 as a whole and individual ASEAN-5 economies to proceed with the SLM test analysis.

3.6. The Dumitrescu-Hurlin Causality Test

Besides exploring the quantitative relationships among the variables, the study also explored their causal relationships to clarify whether the independent variables are determinants of the dependent variables. Due to the existence of cross-sectional dependence in a heterogeneous panel condition, the DH causality test (Dumitrescu and Hurlin, 2012) is an appropriate means of assessing causality in this study. In the ASEAN context, Munir et al. (2020) employed the DH causality test to analyse the causal relationship between economic growth and environmental cleaning related to EKC analysis. The test can be generally formulated as shown below:

$$Y_{it} = \alpha_i + \sum_{k=1}^{k} \beta_{it} y_{i,\,t-k} + \sum_{k=1}^{k} \gamma_{it} x_{i,\,t-k} + \varepsilon_{i,t} \quad (24)$$

Based on Eq. (24), Y_{it} and X_{it} are the two variables explored in the panel. In this study, they represent CE, TR, GDP, and their respective determining factors. By allowing for diversity coefficients among individual economies, the causality test efficiently examines whether X is the cause of Y or the opposite. When = 0 in the heterogeneous panel series test based on the DH causality test, the null hypothesis of homogeneous non-causality is true and cannot be rejected. In contrast, the average Wald test can reject the null hypothesis.

4. EMPIRICAL RESULTS

Table 2 offers the basic information on the variables. As shown in the table, the skewness values indicate a negatively skewed distribution of all the variables except GDP. In terms of distribution for all the variables, the kurtosis is <3, except FDI, which has flat tails. In contrast, FDI has a kurtosis higher than 3, indicating a sharper and higher distribution curve compared to a normal distribution. The SW test (Shapiro and Wilk, 1965) and the SF test (Shapiro and Francia, 1972) revealed that, at a 1% significance level, the null hypothesis was rejected, which indicates that all the variables were not normally distributed. These statistical values showed that all the variables needed further diagnostic tests to ensure the accuracy of the regression results. Furthermore, all the variables were highly correlated, as demonstrated in the correlation analysis section. As indicated by the correlation coefficient between GDP and CE being higher than 0.8, the ASEAN-5 economies strongly link economic growth and environmental degradation.

A cross-sectional dependence between all the variables was confirmed by the finding. By rejecting the null hypothesis of homogeneity, the homogeneity tests implied that the panel was heterogeneous (Table 3). A heterogeneous panel unit root test (Herwartz and Siedenburg, 2008) was conducted in this study, which is the most suitable technique when cross-sectional dependence and heterogeneity are present. All series rejected the null hypothesis at first difference or $I(1)$ (Table 4), which is the statistical result of the heterogeneous panel unit test. According to the traditional panel unit root test, the series integrated at $I(1)$ is typically homogeneous. Nevertheless, the homogeneity test rejects the null hypothesis. Thus, the heterogeneous panel was used. According to the heterogeneous panel unit root test, the model estimation is accurate during the subsequent stage due to the heterogeneous nature of the variables.

The heterogeneous panel cointegration test (Westerlund, 2007) was performed on panels with 500 bootstrap replications in a constant condition. The findings are presented in Table 5. At the 10 and 5% significance levels based on the G_t group statistic, the test rejects the null hypothesis of no cointegration for all models. Nevertheless, it fails to reject the null hypothesis when evaluated using the G_a, P_t, and P_a values. The findings offer valid evidence of long-term cointegration between the variables in all the models in the study.

Table 2: Descriptive statistics and correlation matrix

	CE	TR	GDP	FD	FDI
a) Descriptive statistics					
Mean	0.479	7.256	3.670	1.830	9.393
Median	0.522	7.443	3.564	1.972	9.768
Maximum	1.046	8.119	4.825	2.221	11.047
Minimum	−0.169	5.562	2.662	1.253	0.000
Standard deviation	0.375	0.616	0.537	0.277	2.030
CV	0.782	0.084	0.146	0.151	0.216
Skewness	−0.090	−0.568	0.543	−0.555	−4.097
Kurtosis	1.606	2.230	2.468	1.772	19.264
S-W test	5.669*** (0.000)	5.602*** (0.000)	4.709*** (0.000)	6.846*** (0.000)	7.417*** (0.000)
S-F test	4.450*** (0.001)	4.470*** (0.000)	5.956*** (0.000)	5.596*** (0.000)	8.660*** (0.000)
b) Correlation matrix					
CE	1.000				
TR	0.366*** (0.000)	1.000			
GDP	0.867*** (0.000)	0.528*** (0.000)	1.000		
FD	0.792*** (0.000)	0.163* (0.050)	0.632*** (0.000)	1.000	
FDI	0.289*** (0.000)	0.239*** (0.004)	0.351*** (0.000)	0.320*** (0.000)	1.000

*, **, and ***indicate significance at 10, 5, and 1% levels of significance. Values in ( ) represent the P-value

The Akaike information criterion (AIC), the Schwarz criterion (SC), and the Hannan-Quinn criterion (HQC) were used to identify the lag selection for the PMG estimates using vector autoregression (VAR) estimates. According to these criteria, Table 6 should be used to identify the optimal lags based on panel VAR model estimates. The optimal lag is determined to be 3, as a large sample size is required, and this is based on the minimum AIC value.

All the lagged values of the error correction coefficients were negative and significant, which indicates that a process of adjustment occurs from short-term instability towards a long-term equilibrium condition based on the PMG estimates (Table 7). The first model reveals that trade cooperation significantly impacts carbon emissions. ASEAN-5's carbon emissions will decrease by 0.138% with every 1% increase in trade cooperation with China. The findings indicate that trade cooperation positively impacts environmental cleaning in ASEAN-5 economies, which is in line with the findings from Khan et al. (2022), Destek et al. (2018), and Zhang et al. (2017). This finding also suggests that the PHH does not hold true under this mode of cooperation.

In Model 1, the relationship between carbon emissions and economic growth is also quantified. In the model, the coefficients for GDP and GDP^2 are 2.079 and −0.233, respectively. Both values are statistically significant at the 1% level. The signs for the GDP squared variable substantiate Munir et al.'s (2010) findings. This study also obtained similar results as Lean and Smyth (2010), who selected the ASEAN-5 economies as the research object and observed the EKC hypothesis in ASEAN-5. In addition, according to the study, financial development significantly affects environmental cleaning. The coefficient of FD is 0.394, implying that a 1% increase in financial development will result in a 0.394% increase in carbon emissions in ASEAN-5. The negative impact of financial development on environmental cleaning in the ASEAN-5 economies shares similarities with Ullah et al.'s (2023) findings. They reported that financial development promotes high purchasing power. Such power results in excessive energy consumption, leading to more environmental pollution. Like the findings of Chandran and Tang (2013), who discovered that the effect of FDI on carbon emissions was insignificant in ASEAN-5 economies, this study also acquired the same result.

The empirical results in Model 2 revealed the focal factors that significantly affect economic sustainability. Trade cooperation with China is shown to significantly enhance ASEAN-5 economies' economic growth. The long-run coefficient of TR is 0.440, while the short-run coefficient is 0.286. Like the findings of Huang et al. (2024), the empirical results discovered that trade cooperation boosted ASEAN-5 economies' economic growth in the short term

Table 3: Cross-dependency and homogeneity test

Variables	Statistics	P-value
a) Pesaran's CD test		
CE	2.916**	0.004
TR	16.888***	0.000
GDP	16.702***	0.000
FD	7.396***	0.000
FDI	3.992***	0.000
b) Pesaran-Yamagata homogeneity test		
$\tilde{\Delta}$	−1.720*	0.085
$\tilde{\Delta}$ -adjust	−2.432**	0.015

*, **, and *** indicate significance at 10, 5, and 1% levels of significance. $\tilde{\Delta}$ stands for the delta statistic of Pesaran's and Yamagata's (2008) estimates

Table 4: Herwartz and Sibenburg panel unit root test

Variables	At Level	At first different
CE	2.136	−1.921**
TR	0.660	−2.312***
GDP	1.069	−1.860**
FD	1.778	−1.392*
FDI	−0.993	−1.767**

*, **, and *** indicate significance at 10, 5, and 1% levels of significance

Table 5: Westerlund panel cointegration test results

	Model-1 CE=*f* (TR, GDP, FD, FDI)	Model-2 GDP=*f* (CE, TR, FD, FDI)	Model-3 TR=*f* (CE, GDP, FD, FDI)
a) Group cointegration statistics			
G_t	−8.113*	8.033*	−9.979**
	(0.073)	(0.089)	(0.033)
G_a	−3.999	−0.034	−1.091
	(0.999)	(0.991)	(0.997)
b) Panel cointegration statistics			
P_t	−5.173	−0.199	−3.525
	(0.759)	(0.996)	(0.991)
P_a	−3.243	−0.345	−2.883
	(0.997)	(0.979)	(0.998)

*, **, and *** indicate significance at 10, 5, and 1% levels of significance. Values in ( ) represent the P-value consisting of bootstrapped 500 replications

Table 6: Lag length selection criteria

Lag order	AIC	SC	HQ
1	−16.910	−15.848*	−16.480*
2	−17.218	−15.246	−16.419
3	−17.543*	4.152	−16.376
4	−17.486	−14.662	−15.910

*indicates lag order selected by the criterion

Table 7: The PMG estimation results

	Model-1	Model-2	Model-3
a) Long-run estimates			
CE		1.297 (1.272)	−0.778***
			(0.221)
TR	−0.138*** (0.017)	0.440 ** (0.194)	
GDP	2.079*** (0.282)		3.008***
			(0.501)
GDP^2	−0.223*** (0.029)		
FD	0.394*** (0.077)	−5.521 (4.292)	−0.597 (1.881)
FDI	−0.019 (0.012)	0.773 (0.502)	−0.594 (0.578)
b) Short-run estimates			
ECT_{t-1}	−0.270* (0.146)	−0.048*** (0.011)	−0.041***
			(0.012)
ΔCE		0.637*** (0.232)	−0.157 (0.346)
ΔTR	0.029 (0.021)	0.286*** (0.098)	
ΔGDP	0.0208 (0.847)		0.802***
			(0.100)
ΔGDP^2	0.012 (0.115)		
ΔFD	0.001 (0.022)	0.054 (0.117)	−0.064 (0.118)
ΔFDI	0.0002 (0.002)	−0.018* (0.009)	0.014 (0.010)

*, **, and *** indicate significance at 10, 5, and 1% levels of significance. Values in ( ) represent standard error

Table 8: SLM test for EKC hypothesis

Slope/Hypothesis	Malaysia	Singapore	Thailand	Indonesia	The Philippines	ASEAN-5
Slope at GDP_{min}	3.504	4.207	3.265	2.661	2.971	2.661
Slope at GDP_{max}	4.046	4.825	3.882	3.618	3.533	4.825
SLM test statistic	6.998*** (0.000)	1.470* (0.076)	7.887*** (0.000)	2.120** (0.022)	0.830 (0.208)	9.009*** (0.000)
EKC hypothesis	∩ shape	∩ shape	∩ shape	∩ shape	∪shape	∩ shape

*, **, and ***indicate significance at 10, 5, and 1% levels of significance. Values in ( ) represent P-values

and long term. The quantitative analysis indicated that the effect of FDI on GDP is not significant in the long run. Nevertheless, the coefficient is significant but negative. Similar to the findings of Dinh et al. (2019), this result indicates that FDI has a negative impact on economic growth in the short run. Based on their results, it has been argued in this study that increased FDI does not have economic benefits in the short run. Nevertheless, the positive impact of FDI on economic development remains unclear in the long run. The coefficient on CE in the short run is 0.637 and significant.

Model 3 suggests that environmental cleaning and economic development may significantly impact trade cooperation with China. A 1% increase in environmental pollution results in a 0.778% decrease in trade cooperation with China. The result substantiates the findings of Chen et al. (2023), who identified that environmental degradation had a negative impact on trade cooperation with China. Furthermore, the coefficients of GDP were significant for both the long run and the short run, with values of 3.008 and 0.802, respectively. The findings were validated by the work of Shen (2023). Both studies suggest that economic growth is a decisive factor in trade cooperation with China in ASEAN-5 economies.

The PMG estimates provide empirical relationships that can be used to ensure a preliminary answer to research questions. The empirical evidence also indicates that trade cooperation with China positively impacts environmental cleaning and economic growth in ASEAN-5 economies. Additionally, the EKC hypothesis can be discerned in ASEAN-5. As per the SLM test findings shown in Table 8, the EKC hypothesis follows an inverted U-shape for Malaysia, Singapore, Thailand, Indonesia, and ASEAN-5, indicating that the null hypothesis is rejected. Similarly, the presence of the EKC hypothesis in ASEAN-5 parallels the findings of Munir et al. (2020). By referencing the judge criterion by Samargandi et al. (2015), the Philippines faces a U-shape condition, which cannot support the EKC hypothesis. Nevertheless, the EKC hypothesis in Malaysia was in accordance with the findings of Saboori et al. (2012), with an inverted U-shaped condition. The study observed similar findings to those of Mehmood (2021) and Ike et al. (2020), who discovered evidence confirming the EKC hypothesis in Singapore and Thailand. The EKC hypothesis was also found to hold true in Indonesia and ASEAN-5 based on the results of Alam et al. (2016) and Munir et al. (2020). Thus, the study concludes that the EKC conditions are met by all individual economies in ASEAN-5, except for the Philippines.

The EKC fitting curve displayed in Figure 3 reveals a U-shaped SLM relationship in the Philippines. Notably, it is crucial to consider the country's current situation. The Philippines' current development level remains below the remaining four ASEAN economies. Therefore, an improvement in the Philippines' economic growth will undoubtedly lead to severe environmental pollution issues. Nevertheless, in other economies, the EKC hypothesis is shown to hold true. By combining both the statistical results and the fitting curves, the EKC hypothesis conclusively holds true in Malaysia, Singapore, Thailand, and Indonesia when examined individually and the entire ASEAN-5. These economies have aligned themselves with the green BRI concept in their pursuit of economic development.

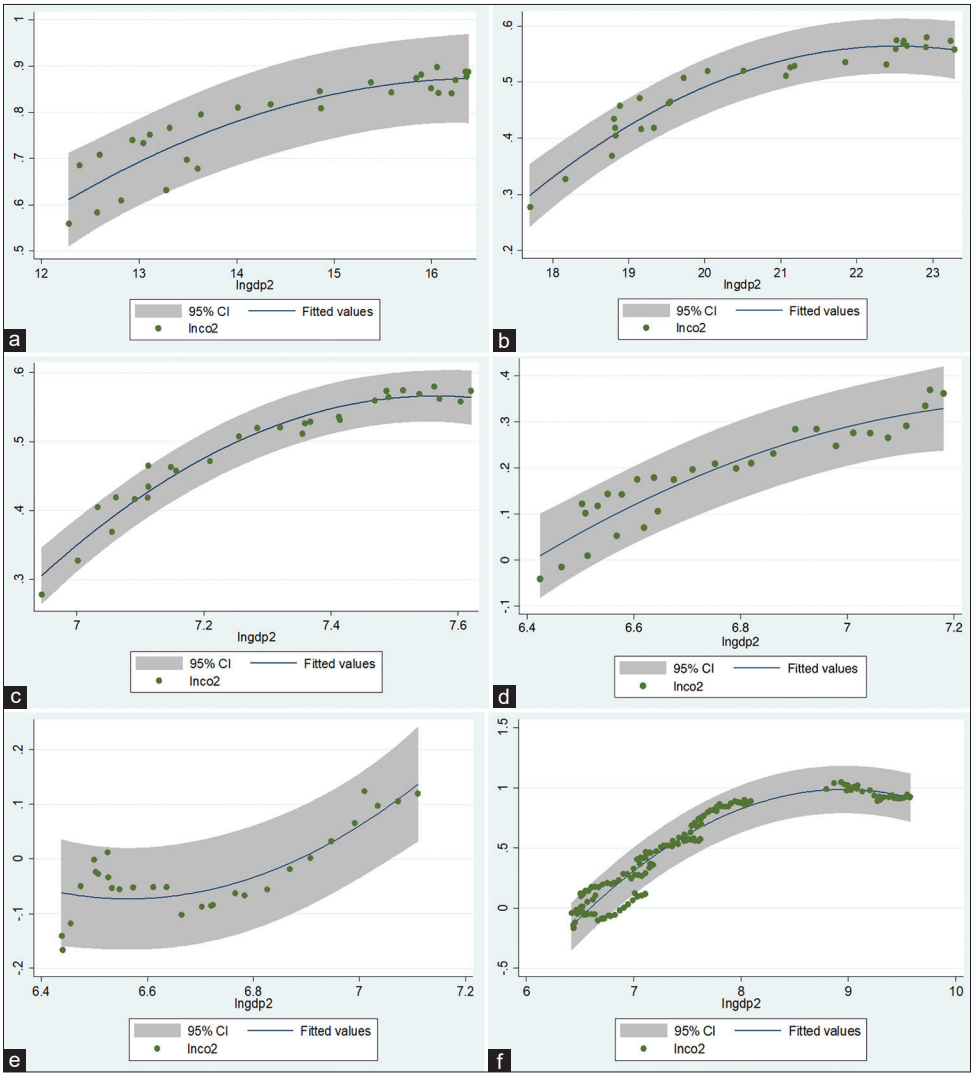
Table 9: DH causality test results

Null hypothesis	W-statistics	P-value	Causality direction
TR −/→ CE	10.014***	0.000	Unidirectional causality
TR ←/− CE	0.385	0.397	
GDP−/→CE	3.649***	0.005	Unidirectional causality
GDP←/−CE	1.948	0.248	
FD−/→CE	1.061	0.972	No causality
FD←/−CE	0.674	0.574	
FDI−/→CE	3.177***	0.004	Bidirectional causality
FDI←/−CE	2.872**	0.015	
TR−/→GDP	4.768***	0.000	Bidirectional causality
TR←/−GDP	3.498***	0.001	
FD−/→GDP	7.679***	0.000	Bidirectional causality
FD←/−GDP	3.411***	0.000	
FDI−/→GDP	0.500	0.425	Unidirectional causality
FDI←/−GDP	6.874***	0.000	
FD−/→TR	1.963	0.233	No causality
FD←/− TR	0.553	0.467	
FDI−/→TR	2.442*	0.065	Bidirectional causality
FDI←/− TR	4.449***	0.000	
FDI−/→FD	4.898***	0.000	Unidirectional causality
FDI←/−FD	0.527	0.446	

*, **, and ***indicate significance at 10, 5, and 1% levels of significance. Values in ( ) represent P-values

The results of the causality test shed light on the causal relationships between all the study's variables (Table 9). Like the findings of Işik et al. (2017), the study observed a unidirectional causal impact of trade cooperation with China and economic growth on environmental cleaning. Bidirectional causality exists between economic growth in ASEAN-5 economies and trade cooperation with China. After combining the coefficients of these variables, the study can conclude that trade cooperation with China and economic growth play a decisive role in decreasing carbon emissions. The bidirectional causal relationship between TR and GDP also implies that trade cooperation can enhance the ASEAN-5 economies' economic development, in turn promoting their trade cooperation with China. According to Rahman and Alam (2022), no causal relationship existed between financial development and carbon emissions. Despite the positive coefficients of financial

Figure 3: SLM test for the EKC hypothesis. (a) Malaysia, (b) Singapore, (c) Thailand, (d) Indonesia, (e) The Philippines, (f) ASEAN-5



development in Model 1, it does not cause environmental degradation.

A bidirectional causal relationship exists between FDI and CE, in line with the findings from Chandran and Tang (2013). Besides, the study concludes that economic development can encourage the inflow of FDI through the unidirectional causal run from GDP and FDI. With continuous economic development, FDI will play a greater responsibility in promoting environmental cleaning. Moreover, the study revealed a bidirectional causal link between TR and FDI but no causal link from FD to TR.

5. CONCLUSIONS AND POLICY IMPLICATIONS

The "Green BRI" initiative aims to unite people of different nationalities to pursue economic growth while prioritising environmental protection. Such a mission is necessary for all state members of the BRI. First, ASEAN-5 should be more proactive in conducting extensive and in-depth trade cooperation with China since such cooperation leads to better environmental conditions and economic development, as proven in this study. The current stage of economic development and collaboration between ASEAN-5 and China supports a mutually beneficial strategy. This approach remains encouraged and motivated, fostering a virtuous cycle that is expected to persist. Secondly, ASEAN-5 economies should ensure that their economic development levels are collectively optimal. Thirdly, the establishment of the BRI in ASEAN-5 should focus on green FDI and technologies that utilise renewable energy in the production sector. Furthermore, the negative impact of financial development on environmental cleaning should not be ignored. The governments of ASEAN-5 economies should promote the development of the green financing system and provide sufficient funding support to the environmental protection industries. Furthermore, ASEAN-5 economies should actively take advantage of the positive effects of FDI and the digital economy, which is supported by all countries. Thus, the ASEAN-5 economies can achieve high-quality transformation in both financial and economic aspects.

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