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THE IMPACT OF EXTENDED TRADE OPENNESS ON ENVIRONMENTAL QUALITY OF RCEP COUNTRIES: ADVANCING THE MEASUREMENT FRAMEWORK WITH THE LOAD CAPACITY FACTOR

Nguyễn Trần Thu Trang[1], Trịnh Ny Na, Nguyễn Lê Khánh Ngân,
Phạm Trịnh Thanh Trúc, Nguyễn Phương Quỳnh

Sinh viên K61 CLC Kinh tế đối ngoại

Trường Đại học Ngoại thương Cơ sở II tại Hồ Chí Minh

Trần Nguyên Chất, Lê Hằng Mỹ Hạnh

Giảng viên Cơ sở II

Trường Đại học Ngoại thương Cơ sở II tại Hồ Chí Minh

Abstract

In the literature on environmental economics, the environmental impact of trade openness remains a controversial topic for years. This study therefore scrutinizes the impact of extended trade openness on the environmental quality of 13 RCEP countries over the 1996-2022 period, except Laos and Myanmar due to data unavailability. A more comprehensive indicator of environmental quality - load capacity factor - is adopted instead of CO_2 emission or ecological footprint. Due to the potential cross-sectional dependence among variables, we employ an econometric approach accounting for this phenomenon. The CIPS and CADF unit root tests indicate that the variables are stationary and according to Westerlund cointegration tests, there exists a long-term relationship among them. The augmented mean group (AMG) results indicate that while trade openness promotes sustainability, energy consumption and FDI inflows escalate the environmental degradation in 13 RCEP countries. Moreover, the findings also confirm the U-shaped EKC relationship between economic growth and environmental quality in the long run. Upon these

[1] Tác giả liên hệ, Email: k61.2212155205@ftu.edu.vn

results, it is suggested that to improve environmental quality, the transfer of environmentally friendly technologies and practices should be utilized and more regulations on the environment should be taken into consideration when concluding mutual agreement among countries.

Key words: trade openness, environmental quality, RCEP, load capacity factor

ẢNH HƯỞNG CỦA ĐỘ MỞ THƯƠNG MẠI MỞ RỘNG ĐẾN CHẤT LƯỢNG MÔI TRƯỜNG Ở CÁC NƯỚC THUỘC HIỆP ĐỊNH ĐỐI TÁC KINH TẾ TOÀN DIỆN KHU VỰC RCEP: PHÁT TRIỂN KHUNG ĐO LƯỜNG VỚI HỆ SỐ CHỊU TẢI

Tóm tắt

Trong các tài liệu về kinh tế môi trường, tác động môi trường của việc mở cửa thương mại vẫn là một chủ đề gây tranh cãi trong nhiều năm. Do đó, nghiên cứu này xem xét kỹ lưỡng tác động của việc mở cửa thương mại mở rộng đối với chất lượng môi trường của 13 quốc gia RCEP trong giai đoạn 1996-2022, ngoại trừ Lào và Myanmar do không có dữ liệu. Một chỉ số toàn diện hơn về chất lượng môi trường - hệ số sức tải - được áp dụng thay cho lượng phát thải CO2 hoặc dấu chân sinh thái. Do sự phụ thuộc tiềm ẩn theo chiều ngang giữa các biến, chúng tôi sử dụng phương pháp tiếp cận kinh tế lượng để tính đến hiện tượng này. Các kiểm định CIPS và CADF chỉ ra rằng các biến là tĩnh và theo các kiểm định đồng tích hợp Westerlund, tồn tại mối quan hệ lâu dài giữa chúng. Kết quả phương pháp nhóm trung bình tăng cường (AMG) chỉ ra rằng trong khi mở cửa thương mại thúc đẩy tính bền vững, thì mức tiêu thụ năng lượng và dòng vốn FDI làm gia tăng sự suy thoái môi trường ở 13 quốc gia RCEP. Hơn nữa, các phát hiện cũng xác nhận mối quan hệ EKC hình chữ U giữa tăng trưởng kinh tế và chất lượng môi trường trong dài hạn. Dựa trên những kết quả này, có ý kiến cho rằng để cải thiện chất lượng môi trường, cần áp dụng chuyển giao công nghệ và biện pháp thân thiện với môi trường và cân nhắc nhiều hơn các quy định về môi trường khi ký kết thỏa thuận chung giữa các quốc gia.

Từ khoá: độ mở thương mại, chất lượng môi trường, RCEP, hệ số chịu tải

1. Introduction

In the context of globalization where multilateral trade accelerates, the degradation of the natural environment is gaining higher and higher concern due to its negative impact on the sustainable development of a nation. This growing urgency has driven research efforts to identify the key factors contributing to environmental degradation (Acaroğlu et al., 2023). Energy consumption, trade openness, and financial development have been noted among others to be highly debated, influencing environmental quality in relation to the documentation of Akhayere et al. (2023), Essandoh et al. (2020), and Latif & Fareed (2023). To be correct, past research is yet to arrive at the proper effect of the identified variables.

Trade liberalization, especially through regional agreements such as RCEP, has increased concern about the environmental impact. Though greater openness to trade leads to economic growth and technological progress, it might be associated with higher resource use and pollution when environmental regulations are not stringent (Awosusi et al., 2022). Most previous studies have considered the environmental effect of trade using CO_2 emissions or the ecological footprint (EFP) as proxies. However, CO_2 emissions are mostly indicative of air pollution and cannot present a wide vision of the ecological destruction; similarly, EFP has also been critiqued for focusing on resource consumption without considering biocapacity. (Akhayere et al., 2023).

To get out of these deficiencies, recent studies have been developing the LCF as a more complete environmental sustainability indicator (Siche et al., 2010). The LCF is estimated as the ratio of biocapacity to ecological footprint; values less than 1 denote unsustainable environmental conditions, while those greater than 1 reflect a sufficient level of resources to fulfill human needs. LCF is a superior indicator than its predecessors since it considers both sides of the equation: demand from the environment and supply (Akhayere et al., 2023).

This study examines the influence of trade openness among 13 RCEP countries on environmental quality, including Brunei-Darussalam, Cambodia, Indonesia, Malaysia, Vietnam, Australia, China, Japan, South Korea, New Zealand, Thailand, Philippines and Singapore. While some studies have done various assessments of the effects of trade agreements, such as Ya Wen et al. (2021) and Li Zhang et al (2022), on CO_2 emissions, no previous studies used LCF as a measure of sustainability in regard to RCEP. This paper tries to fill this gap with a more complete analysis of the environmental impact of RCEP.

2. Literature Review and Theoretical Analysis

2.1. Key concepts

2.1.1. Extended Trade openness

Trade openness has been identified as a significant driver of economic growth, primarily through comparative advantage and efficiency gains (Frankel & Romer, 1999). The classical economic perspective of comparative advantage based on Ricardo's theory states that nations economically benefit by producing goods at their lowest possible cost compared to other nations for international trade exchange. A widely accepted measure of trade openness is the ratio of total trade (the sum of exports and imports) to GDP. However, this measurement has been criticized because of its potential with country size where overestimates in smaller countries and underestimates in larger countries (Tang, 2011). Researchers have proposed alternative approaches, including value-added trade measures (Belke & Wang, 2005); similarly, the ratio of value added destined for exports (VADE) to GDP is suggested as a more accurate measure of trade openness (Larudee, 2012) and composite indicators that account for a country's global trade significance (Squalli & Wilson, 2006).

Building on this, the role of FDI emerges as a critical factor, the increased trade in intermediate inputs, import substitution or exports is encouraged by FDI according to Golberg and Klein (1998). "Tariff jumping" FDI often arises from trade restriction and companies opt to set up local production due to desire to circumvent the trade barriers and gain access to the domestic markets (Liargovas & Skandalis, 2012). Given the shortcomings of the conventional metric, Dou et al. (2021) developed a new trade openness indicator that provides a more holistic lens for understanding the interplay between trade and investment in the global economy. With FDI serving as a stimulant for export-oriented production and import demand, this extension reflects the growing recognition that trade and investment are interdependent, furthering economic globalization.

Trade openness, in addition, has a significant influence on environmental outcomes through 3 primary aspects: the scale effect, composition effect and technique effect (Copeland & Taylor, 1994; Grossman & Krueger, 1991). The scale effect refers to the increase in trade and production that can heighten resource use and pollution, particularly in manufacturing hubs like China within RCEP, which exhibited a negative scale effect from increased export demand (Chai, 2000). The composition effect states that trade can impact the industrial composition (e.g. change the type or amount of production) towards more polluting sectors, by documenting Vietnam's export driven growth and associated deforestation (Meyfroidt & Lambin, 2009; Nguyen 2022). On the contrary, the technique effect says that countries that export goods may be incentivized to use cheaper, more environmentally friendly production techniques as well as to enforce stringent environmental policies to meet those same environmental standards of foreign partners, such as the case of Pakistan's exports moving towards varieties with lower carbon emissions (Haq et al., 2022). Recent research has focused on empirically estimating these effects and understanding the interaction between trade, growth and environmental outcomes (Cherniwchan & Taylor, 2022). This variability underscores the complexity of balancing trade-driven growth with ecological sustainability.

2.1.2. Environmental quality

Environmental quality is a broad concept that encompasses various aspects of the natural environment including air quality, water quality and ecosystem health. It refers to the state of the environment in relation to factors affecting human and ecological well-being. Environmental sustainability is one of the critical issues that the global community is currently facing and addressing (Aydin et al., 2024). Therefore, the measurement of the environmental quality is crucial in understanding the health of ecosystems and informing policy decisions (Pata et al., 2023b). One of the most popular measurements for environmental degradation is CO2 emission as it accounts for the majority of greenhouse gas emissions and climate change (Luo et al., 2023). However, a recent study by Nathaniel et al. (2021) noted that CO_2 as an indicator does not represent the individual effects of environmental degradation and it just focuses on air quality only (Ongan et al., 2022). To complement this weakness, the ecological footprint has recently been increasingly used in current studies as a broader indicator of environmental degradation. The latest examples of the studies that investigated the nexus between energy consumption and ecological footprint include Al-Mulali et al. (2016), Destek and Sinha (2020), and Pata and Caglar (2021). Despite these strengths, the ecological footprint primarily measures human demands on natural resources, but fails to account for nature's capacity to supply these demands, which is called biocapacity. Therefore, it is important for future research to consider both ecological footprint and biocapacity in order to provide a more comprehensive understanding of environmental sustainability.

The load capacity factor (LCF) is an indicator of environmental sustainability, providing a comprehensive assessment of a country's environmental health and helps identify whether a region is living within its ecological means (Awosusi et al., 2022). The LCF is measures the balance between the supply of natural resources (biocapacity) and the demand placed on those resources (ecological footprint) Aydin et al. (2024) which formulated byF (Siche et al., 2010):

$$LCF = \frac{BIO}{EF}$$

An LCF greater than 1 indicates that a region's biocapacity exceeds its ecological footprint, suggesting environmental sustainability. A value below 1 indicates an unsustainable situation. In other words, an effective criterion for assessing environmental sustainability is the value limit of 1 (Pata, 2021).

2.2. Theoretical framework

The Environmental Kuznets Curve (EKC) hypothesis was developed in the early 1990s, regarding the connection between economic development and environmental degeneration, namely, that as a country's per capita income increases, environmental quality initially decreases and then subsequently increases to some threshold income. The curve is approximately of an inverted U shape and the peak of the curve denotes the turning point after which environmental improvement starts (Kuznet, 1995).

This hypothesis has been extensively tested in the empirical literature, however the validity of the EKC hypothesis remains mixed. While other studies find support for it, especially when using global pollution proxies and sub-national data (Haider Mahmood et al., 2023), while others have not (Galeotti et al., 2008). The EKC model's shortcomings in encapsulating the complexities of environmental quality are further highlighted by criticisms. According to Stern in 2004 the fundamental framework simplifies how social economic variables connect with environmental effects through its direct income-environment correlation assumption. This method disregards important components associated with governance together with trade patterns and technological development and regional agreements like RCEP and their environmental effects.

However, the EKC framework has and continues to be a valuable point of reference in environmental quality research as it provides a lens for economic environmental tradeoffs (Kijima et al., 2010). Its emphasis on income-driven transitions provides a starting point for analyzing policy interventions, such as emission standards or green technology adoption, that might accelerate the turning point. This study leverages the EKC as a conceptual framework, while addressing its limitation by incorporating additional factors such as trade openness and other ecological variables to better explain environmental quality trends in contemporary settings, particularly within the context of RCEP's diverse economic and environmental landscape.

2.3. Empirical researches and hypothesis

2.3.1. Trade openness and environmental quality

The impact of trade openness on the environment is a subject of ongoing debate and research, with no clear consensus on the relationship between the two (Zilberman, 1992; Chhabra et al., 2023). Benzerrouk et al. (2021) provide evidence showing that developing countries with low environmental standards attract polluting industries from high-income countries, leading to increased emissions and environmental harm. Likewise, the study of Barkat et al. (2024) on 20 OECD countries between 1870 and 2019 indicated trade openness had a positive effect on CO2 emission which suggests deterioration of environmental quality. This is supported by findings of Balsalobre-Lorente et al. (2018) of 5 EU nations, Rehman et al. (2021) in Pakistan.

On the other hand, Reppelin-Hill (1999) found that greater trade openness was associated with faster adaptation of cleaner electric arc furnace technology in the steel industry across countries. Essandoh et al. (2020) claimed in their study that developed countries tend to reduce CO_2 emissions in the long run through trade-related knowledge spillovers, especially in nations with strong human capital and other enabling factors. Haseeb et al. (2023); Jahanger et al. (2022) also concluded that trade openness leads to environmentally sustainable growth through eco-innovation and financial development. According to research by Wang and Zhang (2021), trade openness lowers CO_2 emissions in high-income nations while increasing them in low-income ones, supported by Le et al, 2016. Recent study of Wang & Li (2024) on 114 nations shows it lowers environmental damage hereby decreasing CO_2 while fostering economic growth. Huilan et al. (2024) using LCF as an indicator of environment, discover a positive relationship between the two variables. Therefore, it can be inferred that trade openness plays a crucial role in the environmental impacts both in long term and short term. In this thesis, the author proposed that:

H_1: There is a positive relationship between Trade Openness and Environmental Quality.

2.3.2. Economic growth and environmental quality

The relation between GHG and GDPpc has been extensively studied, particularly in the context of the aforementioned EKC hypothesis. In essence, the empirical studies have shown mixed results regarding the EKC hypothesis which highlights the importance of considering various econometric approaches and incorporating additional explanatory variables for a more comprehensive understanding of this relationship.

There is an EKC pattern found to be valid for CO_2 emissions in 1960-2015 (Beşer & Beşer, 2017) and in ASEAN nations between 1980-2006 (Lean & Smyth, 2010). A finding of Liu et al. (2021) by using panel models for tropical nations come to a result that there is a negative impact of GDPpc and terrestrial carbon sequestration capacity in the low and lower-middle income countries, but do not consistently lead to predictable changes in environmental quality for the upper and high-income countries. This conclusion is supported by several empirical results: Li & Lin (2013); Azam & Khan (2016). However, it is said by other researchers that CO_2 and GDPcp have a monotonically increasing linear relationship, rejecting the EKC hypothesis (Galeotti et al., 2006; Abid, M., 2016). The result of Wahyudi (2024) for Indonesia in 1990-2021 and found a positive relationship between CO_2 emission and GDP per capita in both long and short run.

Mainly the studies we could find focusing solely on CO_2 emissions might mask the overall environmental impact and create a misleading relationship between economic growth and environmental quality. Hereby, the author's research expects that initial economic growth might negatively affect LCF, subsequent development of technological advancements and policy changes could lead to improvements in both LCF and overall environmental performance.

H_2: There is a positive relationship between Economic Growth and Environmental Quality in the long run.

2.3.3. Urbanization and environmental quality

Urbanization is a defining feature of contemporary global development, with more than a half of the world’s population currently residing in urban areas (UN-habitat, 2020). In fact, the impact of urbanization on the environment are manifold, including increased resource consumption, waste generation and pollution emissions (Seto et al., 2014; Sinevičienė et al., 2018), as well as potential benefits from agglomeration economies and technological advancements (Batty et al., 2012; Chikaraishi et al., 2015).

The research for 34 OECD countries between 1960-2010 (Wang et al., 2015) and 29 provinces of China over the period 1995-2013 (He et al., 2017) respectively found the existence of an inverted U-shaped relationship between urbanization and measures of environmental pollution. The findings of W. Wang et al. (2021) of OECD stated that the impact of urbanization on CO_2 was insignificant compared to its production. Another result from OECD nations in the 1980 to 2018 time frame of Guloglu et al. (2023) showed that higher levels of urbanization were associated with poorer environmental outcomes. Raihan et al. (2023) employed ARDL method to find that between 1971 and 2018, the load capacity factor diminished in Mexico in line with the growth of urban centers and population density; this conclusion is supported by similar findings for E7 countries of Zhu et al. (2023). Therefore in this context, the authors hypothesize that urbanization reduces the environment quality hence have negative correlation with LCF.

H_3: There is a negative relationship between Urbanization and Environmental Quality.

2.3.4. Energy consumption (Primary energy consumption per capita)

Energy consumption is one of the major determinants of environmental quality because it shows the level of use of resources and their related environmental impacts. According to Robert B. Jackson et al. (2022), there is a very complex relationship between energy consumption and well-being. While higher per-capita energy use does point toward better quality of life and economic growth, it also normally results in environmental degradation. The trade-off indeed calls for a sustainable approach toward energy consumption, especially in the developing regions.

Kahouli (2019) tested the contribution of energy consumption to economic growth, using a sample of 34 OECD countries over the period 1990-2015. A unidirectional relationship was observed; hence, increasing energy consumption leads to economic growth, which consequently degrades the environment.

35 OECD countries within the period of 2000-2014 are taken into consideration using broad proxies of environmental degradation like ecological footprint and environmental performance index by Ozcan and Ozturk (2019) have shown the similar result. According to Jing Li et al. (2023), the effect of energy use and economic growth on carbon dioxide emissions in the period from 1992 to 2016 was analyzed by the Panel ARDL model show a positive impact on the factors of CO_2 emission, drawing a vivid picture of the environmental consequences of increased energy consumption. The study expected that increasing energy consumption would reduce environmental quality, thereby proposing the hypothesis:

H_4: There is a negative relationship between Energy Consumption and Environmental Quality.

2.3.5. Foreign direct investment and environmental quality

The Pollution Haven Hypothesis is frequently used in theoretical perspectives on how FDI inflows affect the environment. According to this hypothesis, incoming FDIs have negative implications for the environmental quality of the host countries (Doytch, 2020). The results of Solarin et al. (2017) and Koçak and Şarkgüneşi (2017) indicate the existence of PHH in Turkey 1974–2013 in Ghana from 1980 to 2012, respectively. In contrast, Adams et al. (2021) indicated that FDI inflows and net inflows contribute to the general reduction in CO_2 emissions; they have greater effects on territorial-based ones, corroborating the PHE.

Wang et al. (2023) investigated the effect of FDI on carbon emissions at various levels of economic development. In this respect, the authors summarized that FDI may worsen environmental degradation in developing economies since it imports lax environmental standards into the country. Conversely, FDI in developed economies with sound institutional frameworks often aligns with sustainability. Same conclusion made by Al-Mulali and Tang (2013) investigated the impact of FDI on CO_2 emissions within 66 developing countries from the period between 1980 and 2008. Shahbaz et al. (2015) who researched 19 African countries for the period 1980-2010 and Dhrifi et al., (2019) research on 98 developing countries in 1995 - 2017 period reached comparable conclusions. Zhu et al. (2016) came to the conclusion that in order to draw foreign direct investment, there is frequently a tendency to overlook environmental concerns during the construction and development process and to loosen environmental regulation. Therefore, the author proposed:

H_5: There is a negative relationship between FDI and Environmental Quality.

3. Research method

3.1. Theoretical model specification

Thanks to the empirical literature of Pao and Tsai (2010), Farzanegan and Markwardt (2018), and Shahbaz et al. (2017) in other groups, this research focuses on investigating the impact of trade openness on environmental quality in RCEP countries by using urbanization, GDP, energy consumption, and FDI as control variables. To follow the objective, we develop a model by using a theoretical approach

$$\boldsymbol{LCF = f(TO_{it}, GDP_{it}, URB_{it}, EC_{it}, FDI_{it})} \tag{1}$$

where LFC stands for load capacity factor used as a proxy of environmental quality, TO which is the variable of interest represents trade openness, GDP represents the gross domestic product, EC denotes energy consumption, URB represents urbanization, and FDI stands for foreign direct investment.

Then, to validate the environmental Kuznets theory, Eq. (2) is reformulated in to an EKC framework using the non-linear regression model which is specified as:

$$\boldsymbol{LCF = \alpha_0 + \beta_1 TO_{it} + \beta_2 GDP_{it} + \beta_3 lnGDP2_{it} + \beta_4 URB_{it} + \beta_5 EC_{it} + \beta_6 FDI_{it} + \varepsilon_{it}} \tag{2}$$

where i and t stand for individual cross-sections (country levels) and time in years, respectively; β1, …., β5 also represent load capacity factor responding to the change of trade openness, GDP, energy consumption, urbanization and FDI respectively.

In addition, all variables are transformed into a natural logarithm in order to purposely minimize the issue of heteroskedasticity. Notably, log-linear variables give direct elasticities which facilitate interpretation Ehrlich (1996). Hence, the non-linear load capacity factor function for the transformed log-non-linear model in a panel specification is formulated as:

$$\boldsymbol{LCF = \alpha_0 + \beta_1 lnTO_{it} + \beta_2 lnGDP_{it} + \beta_3 lnGDP2_{it} + \beta_4 lnURB_{it} + \beta_5 lnEC_{it} + \beta_6 FDI_{it} + \varepsilon_{it}} \tag{3}$$

where GDP2 is the square of economic growth whose respective parameter estimates are required to evaluate the ECK hypothesis.

The logarithmic quadratic function for the long-term relationship between economic growth and CO2 emissions is thought to be predicted by the EKC conjuncture. Therefore, this article will demonstrate the opposite link between environmental quality and load capacity factor. Therefore, with regard to the validation of the EKC hypothesis, both positive and negative signals are hypothesized for β_2 and β_3, respectively. β_5 is also thought to have a negative impact on LCF since higher energy consumption leads to a lower load capacity factor, which has a negative impact on environmental quality. Additionally, it is theorized that β_1 can be either positive or negative. A negative correlation could imply that the more open commerce has resulted in fewer polluted counties. On the other hand, high emissions could be a harbinger of good things to come because the countries involved may have desirable, industry-intensive industries that pollute the environment. Last but not least, β_4 is anticipated to be negative since any significant urban population growth results in increased energy consumption and worse environmental quality.

3.2. Estimation technique

To examine the impact of trade openness on environmental quality in RCEP countries, the study uses panel data regression methods. Specifically, to evaluate whether the pooled regression model (POLS), fixed effects model (FEM) or random effects model (REM) is suitable for the data set, the authors performed the Lagrange multiplier test and the Hausman test. Then, the Driscoll-Kraay regression model and generalized least squares (GLS) were applied to overcome the defects such as heteroscedasticity and autocorrelation in the model. After testing for cross-sectional dependence, stationarity and cointegration, the authors used the Augmented Mean Group (AMG) regression method to simultaneously overcome the defects such as heteroscedasticity, autocorrelation, slope homogeneity, and endogeneity of the model. The AMG method was recently developed by Bond and Eberhardt (2013). According to advantages, this estimator allows for the analysis of non-stationary variable parameters and also accounts for national heterogeneity. Regarding the first stage of the AMG estimation approach, the following regression model is used to estimate the study's primary econometric model from Equation (3) using the first-difference form in conjunction with T − 1 dummies:

$$\boldsymbol{\Delta LCF = \beta_1 \Delta TO_{it} + \beta_2 \Delta GDP_{it} + \beta_3 \Delta GDP2_{it} + \beta_4 \Delta URB_{it} + \beta_5 \Delta EC_{it} + \beta_6 \Delta FDI_{it} + \varepsilon_{it} + \sum_{t=2}^{T} c_t(\Delta D_t)} \tag{4}$$

where ΔD_t is the first difference of T − 1 time dummies; c_t is the is the period dummies' coefficients

Secondly, the AMG approach is expressed in a dynamic process by reparametrizing c_t at time t into u_t

$$\Delta LCF = \beta_1 \Delta TO_{it} + \beta_2 \Delta GDP_{it} + \beta_3 \Delta GDP2_{it} + \beta_4 \Delta URB_{it} + \beta_5 \Delta EC_{it} + \beta_6 \Delta FDI_{it} + \varepsilon_{it} + u_t(d_t) \quad (5)$$

Where

$$\Delta LCF - u_t(d_t) = \beta_1 \Delta TO_{it} + \beta_2 \Delta GDP_{it} + \beta_3 \Delta GDP2_{it} + \beta_4 \Delta URB_{it} + \beta_5 \Delta EC_{it} + \beta_6 \Delta FDI_{it} + \varepsilon_{it} \quad (6)$$

Equations (5) and (6) imply that the mean values for the parameter estimations with regard to country-specific models are calculated after the panel regression model with u_t is adjusted.

The following connection can be used to derive estimates of the explanatory variables based on the AMG estimator βi:

$$\beta_{1,AMG} = \frac{1}{N}\sum_{i=1}^{N} \beta_{1i}, \quad \beta_{2,AMG} = \frac{1}{N}\sum_{i=1}^{N} \beta_{2i}, \quad \beta_{3,AMG} = \frac{1}{N}\sum_{i=1}^{N} \beta_{3i},$$
$$\beta_{4,AMG} = \frac{1}{N}\sum_{i=1}^{N} \beta_{4i}, \quad \beta_{5,AMG} = \frac{1}{N}\sum_{i=1}^{N} \beta_{5i}, \quad \beta_{6,AMG} = \frac{1}{N}\sum_{i=1}^{N} \beta_{6i} \quad (7)$$

3.3. Variable settings and data sources

In the current study, research has explored the panel data of RCEP countries from 1996 to 2022. Due to restrictions on the availability of data, this paper just investigates 13 out of 15 RCEP countries for the period of 27 years, which exclude Laos and Myanmar from the data set. Load capacity factor has been taken as a dependent variable, while trade openness is an independent variable. The control variables in this study are GDP, urbanization, energy consumption, and FDI. All of this information will be extracted from the World Bank (2024), Transcend (2024). The way how to identify and calculate both dependent variable and independent variables, and the detailed descriptive statistics of all the variables are depicted in the Table 1, Figure 1 respectively:

Table 1: Definition, equation and source of dataset

Variable	Symbol	Definition	Measurement	Data source
Load capacity factor	LCF	Environmental quality	$\frac{biocapacity\ (gha\ per\ }{ecological\ footprint\ (gha}$	Transcend (2024)
Trade openness	TO	Country's trade and financial openness relative to its GDP and the world economy	$\frac{T_{it} + F_{it}}{GDP_{it}} * \frac{1}{1 - \frac{GDP_{it}}{WGDP_t}}$ T_{it} : total trade of country i in year t, F_{it}: total inward foreign investment GDP_{it}: total GDP $WGDP_t$: world total GDP.	Dou et al. (2021) World Bank (2024)
Gross Domestic Product	GDP	Economic growth (GDP per capita constant $US)	$\frac{GDP}{population}$	World Bank (2024)
Urbanization	URB	Number of urban population (in thousands)		World Bank (2024)
Energy consumption	EC	Energy use (kg of oil equivalent per capita)		World Bank (2024)
Foreign Direct Inflow	FDI	The inflow of foreign direct investment relatives to the GDP	$\frac{Net\ inflow}{GDP}$	World Bank (2024)

Table 2: Descriptive statistics of dataset (in natural logarithmic form)

Variable	Observation	Mean	Standard Deviation	Min	Max
LFC	351	0. 648	0.551	0.006	2.440
lnTO	351	4.615	0.857	0.181	6.116
lnGDP	351	8.957	1.528	5.556	11.390
lnGDP2	351	82.556	26.603	30.869	129.731
lnURB	351	16.773	1.888	12.237	20.615
lnEC	351	9.987	1.359	6.414	12.013
FDI	351	0.043	0.057	-0.038	0.316

4. Result and discussion

4.1 Cross-sectional dependence

Taking into consideration the similarities of geography and socio-economy among RCEP countries, the residual cross-sectional dependence test is employed to examine whether there are inter-sectoral dependencies in panel data. This paper used both Pesaran (2004) and Breusch-Pagan LM Test (1998) to ensure the efficiency and robustness of the result. As shown in Table 2, results obtained by Pesaran and Breusch-Pagan are quite similar. Most of the variables witness strong cross-sectional dependence, excepting for FDI. FDI, however, had a relatively weak residual cross-sectional correlation while the variable can not reject the null hypothesis in the Pesaran test. This can be explained by foreign investment could be influenced by common global factors such as trade policies and incentives among country groups, leading to heterogeneous effects rather than uniform dependence.

Table 3: Results from the Pesaran CD and Breusch-Pagan LM test

Variable	Pesaran CD test	Breusch-Pagan LM Test
LCF	10.296*	812.121*
lnTO	14.962*	608.176*
lnGDP	39.422*	1623.102*
lnGDP2	39.258*	1613.674*
lnURB	44.650*	1995.985*
lnEC	12.175*	1269.080*
FDI	0.367	204.809*

** indicates 1% significance level.*

The Pesaran CD test executes the null hypothesis of cross-sectional independence.

4.2 Panel unit root test

As the panel data across RCEP countries has the ability of cross-sectional dependence, CIPS and CAFD unit root tests were employed rather than LLC or Breitung tests (Tachie et al., 2020). The results of two panel unit root tests (CIPS and CAFD) are shown in Table 3. Under the condition of no difference, all the variables are non-stationary, indicating that the data has unit root. However, at first difference, all the p values of tests were less than 0.05, rejecting the null hypothesis of homogeneous non-stationary. In summary, the selected variables are integrated in the same order.

Table 4: Panel unit root tests result

Variable	Test method	At level		At 1st difference	
		Without trend	Trend	Without trend	Trend
LCF	CIPS	-2.836*	-2.964*	-4.950*	-5.380*
	CAFD	-2.374**	-2.521	-3.652*	-3.764*
lnTO	CIPS	-1.019	-2.63	-4.038*	-4.136*

Variable	Test method	At level		At 1st difference	
		Without trend	Trend	Without trend	Trend
	CAFD	-0.829	-2.779**	-3.205*	-3.191*
ln GDP	CIPS	-2.854*	-3.113*	-4.183*	-4.165*
	CAFD	-3.003*	-3.495*	-3.883*	-3.951*
lnGDP2	CIPS	-2.658*	-3.216*	-4.234*	-4.198*
	CAFD	-2.902*	-3.393*	-3.808*	-3.822*
lnURB	CIPS	-1.949	-2.624	-2.819*	-3.610*
	CAFD	-1.988	-2.501	-2.726*	-3.831*
lnEC	CIPS	-2.195	-2.059	-4.379*	-4.466*
	CAFD	-1.908	-1.924	-3.148*	-3.477*
FDI	CIPS	-3.243*	-4.131*	-5.569*	-5.654*
	CAFD	-2.607*	-3.389*	-4.621*	-4.628*

*,**,*** *indicates 1%, 5%, and 10% significance level, respectively.*

4.3 Panel cointegration test

In order to examine whether there is a long-term stable relationship among sets of data, the study used panel cointegration test by Westerlund and Edgerton. Result is shown in Table 4. The result, counting panel specific time trends, rejects the null hypothesis of no cointegration across all panels at 1% significance level. The Westerlund cointegration test confirmed that the selected panel data has a long-term cointegration relationship, allowing for long-term equilibrium estimation can be carried out.

Table 5: Westerlund cointegration test result

	Statistic	p-value
Westerlund variance ratio	-1.3489	0.0887

Panel means and time trend are included.

4.4 Long-run estimation

Since the long-run relationship has been established among variables, and to solve the problem of autocorrelation, heteroskedasticity, and possibility of slope heteroskedasticity, this study adopted the AMG estimator as the main long-term estimator. Table 5 indicated the long-run estimation effects of trade openness (TO), economic growth (GDP and GDP2), urbanization (URB), energy consumption (EC) and FDI on load capacity factor (LCF) based on the mentioned approach.

Table 6: AMG long-run estimation results

Variable	Coefficient	Std. error	p-value
lnTO	0.063*	0.018	0.00
lnGDP	-1.359**	0.682	0.046
lnGDP2	0.072**	0.035	0.039
lnURB	0.338	0.419	0.419
lnEC	-0.113*	0. 036	0.001
FDI	-0.051***	0.029	0.076
Wald chi-square test			
Statistics	34.25*		
Prob.	0.00		

,,*** indicates 1%, 5%, 10% significance level, respectively.*

According to the table, trade openness has a positive effect on LCF, meaning that it has a positive effect on the environmental quality of these countries. Specifically, the 0.0632 coefficient implies that a percentage increase in trade openness will result in a 0.0632% increase in the quality of environment - with LCF being the proxy - in 13 countries of RCEP, supporting the first hypothesis of this paper. There are some reasons that explain why trade openness fosters positive effects on environmental quality. The integration of economies into global markets aligns with the technique effect by forcing them to implement stricter environmental regulations and purchasing more energy-efficient technologies that decrease environmental pollution. This policy enables advanced production technologies and environmentally safe production processes to transfer from developed to developing nations. In addition, the collaboration across nations which trade also brings further develops environmental consciousness so countries adopt stricter environmental regulations as a result. Trade agreement member nations usually accept responsibilities to decrease emissions by embracing international environmental policies together with sustainable development goals. Beside that, trade barriers are removed to promote industry centers, so that they can relocate their production from more polluting to less polluting sectors. This helps countries to discontinue energy-dependent manufacturing thus encouraging the shift towards environmentally friendly service sectors that produce lower levels of carbon dioxide emissions. Through foreign trade these investigated countries can fund both sustainable infrastructure and renewable power generation systems which minimize their environmental impact. Therefore, scale effect is not supported by this article. In conclusion, the finding above further reinforces the findings of Dogan and Turkekul (2016) for the USA, Afridi et al. (2019) for the SAARC region, Tachie et al. (2020) for EU-18 countries; and Karedla, Mishra and Patel (2021) for India.

For the economic growth factor, using GDP as the measurement, the relationship with the dependent variable is inverse: one percent increase in GDP per capita will lead to 1.359% decrease in the biodiversity-ecological footprint ratio; while in case GDP per capita is squared, environmental quality is enhanced with the percentage of 0.725%. This result validates the existence of a U-shape relationship between GDP and LCF, adhering to the aforementioned EKC model. Obviously, at the beginning stage of economic development, countries in RCEP focus on increasing trade, growing investment, thus increasing the demand of energy and the deterioration of the environment (Tachie et al., 2020). However, when the economic growth reaches a certain level, it will raise the environmental awareness among its citizens, leading to a reduction in pollution (Zaidi et al., 2018).

In addition, it is not surprising that the consumption of energy has a negative liaison with environmental quality, with the result showing that energy use will result in a 0.113% of environmental deterioration at a 1% connotation level, ceteris paribus. This conclusion confirms the empirical result of Wen et al. (2024), covering a group of South Asian countries; Tanveer et al. (2021) for Pakistan; Nathaniel and Adeleye (2021) for selected African countries; Ahakwa (2023) for developing countries along the Belt and Road route. The negative relationship between energy consumption and environmental quality supports the fact that RCEP economies follow a fossil fuel-centric pattern, which is a weakness of those countries when relying too much on fossil fuel poses them a threat to more serious environmental degradation (Chen and Zhang, 2024).

Apparently, the variable urbanization is not statistically significant because it has a large p value which is approximately 0.419. With this value, we cannot reject the null hypothesis and must conclude that this variable is not statistically significant, whether at 1%, 5% or 10%. Therefore, we cannot draw any conclusions about the impact of urbanization on environmental quality.

Contrasting to the proposed hypothesis, FDI is evidenced to have a negative impact on LCF indexThis figure can be interpreted in terms of percentage that, ceteris paribus, 1% increase in FDI net inflow out of GDP will lead to 0.0516% degradation of the environment. One reason explaining this relationship is related to corruption, enabling the inflow of low-quality FDI, reducing the spillover effect of FDI, which is the case recorded in China (Wang, Wang and Sun, 2020). Another reason can pertain to the low-income countries, which do not have enough resources to adopt cleaner technologies (Lyubov Tsoy and Heshmati, 2023).

It is imperative that the result gives a post-estimation test examining the validity of LCF and joint significance of independent and control variables using the Wald chi-square test statistic. Specifically, the Wald chi-square statistic is significant at 5% significance level, indicating that the LCF predictive panel model in this study is well-determined and efficient enough to create robust outcomes.

5. Conclusion

This study presents a thorough examination to evaluate trade openness effects on environmental quality through analysis of economic growth alongside added variables, including urbanization rates, energy consumption and foreign direct investment (FDI). The analysis spans 1996 to 2022 for 13 RCEP countries except Laos and Myanmar because these countries lack data availability. The results show that our main variable - extended trade openness - increases environmental quality, validating its technique effect on the environment. Besides, economic growth in the long run also contributes to a more sustainable environment, confirming the EKC hypothesis. FDI and energy consumption, on the other hand, reduce sustainability levels in the region, meaning that RCEP countries, in general, follow the Pollution Haven Hypothesis.

Upon the findings with the presence of the technique effect, this study suggests that RCEP should promote the transfer of environmentally friendly technologies and practices to reduce pollution. In other words, strengthening sustainable trade requires that countries adopt clean investments together with green technology exchanges. The governments therefore should include environmental regulations in trade agreements while implementing rigorous assessments for foreign investments enabling pollution-causing industries to stay out of the RCEP economies. Moreover, the accelerated transition towards the EKC can be achieved through environmental education developments combined with sustainable industrialization policies which boost green economic growth and environmental consciousness. The RCEP members will achieve enhanced environmental sustainability through improved regional collaboration for harmonizing environmental policies and standards.

The study applies a strict econometric framework yet researchers must handle existing limitations for future work. Firstly, a period assessment from 1996 to 2022 offers extensive temporal insight but fresh policy changes might exist beyond this analysis scope. Secondly, the lack of data availability in Laos and Myanmar, reducing the number of countries from 15 to 13, makes this paper not totally comprehensive in investigating the trade-environment nexus among RCEP countries. Thirdly, the panel regression method produces universal findings that exclude specific national characteristics which require independent country studies to examine local variables. Future research must address these gaps because they will help establish better knowledge of sustainable trade practices as well as environmental policymaking in the RCEP region.

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