Journal of Commerce Management and Tourism Studies, Volume 2 Number 3 (Dec 2023), p. 230—238
e-issn 2964-9927 ©Yayasan Mitra Persada Nusantara
http://ympn.id/index.php/JCMTS

Developing economies and environmental impact: A VECM analysis of external debt, ODA, and CO_2

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Abstract - The objective of this study is to examine the carbon dioxide (CO_2) emissions in Asian economies between 1990 and 2019, with a specific focus on their relationship with net official development assistance (NODA) and external debt. Utilizing the IPAT model as a theoretical framework, we employ various econometric methodologies to estimate both long-term and short-term outcomes. These methodologies encompass panel unit-root tests, cointegration techniques, and the VECM method. The findings of the research provide additional substantiation for the presence of cointegration among all variables. The analysis of long-term data revealed a robust and statistically significant relationship between gross domestic product (GDP) and carbon dioxide (CO_2) emissions. Conversely, a strong and inverse connection was identified between foreign debt and net official development assistance (NODA). The results indicated a modest but favorable relationship between the size of the Asian population and the levels of CO_2 emissions. The segment of recommendations encompasses comprehensive proposals and an extensive examination of various alternatives.

Keywords: external debt; ODA; CO_2; VECM

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I. INTRODUCTION

Energy has a pivotal role in the functioning of the global economy. A reliable energy supply is essential for various aspects of societal development, including economic growth, technical innovation, job creation, business continuity, and technological advancement (Tong et al., 2020). Although it is indeed accurate that industrialization has a positive impact on global GDP, it also presents significant environmental hazards. Industrialization's energy consumption and the resulting emission of carbon dioxide (CO_2) are responsible for a range of adverse environmental consequences, including air pollution and global warming. Azwar (2019) posits that the process of industrialization is associated with an exacerbation of environmental degradation. Achieving a harmonious equilibrium between the utilization of renewable and nonrenewable resources is vital for the promotion of sustainable development. In recent decades, there has been a significant emphasis among scholars on analyzing the impact of macroeconomic factors on carbon dioxide (CO_2) emissions. The escalation of carbon dioxide emissions has emerged as a significant catalyst for climatic change, leading to the warming of the atmosphere, oceans, and land (Gallego et al., 2015). According to Clark (2007), the United Nations Framework Convention on Climate Change (UNFCCC) asserts that global climate change, which may be attributed to human activities that substantially modify the composition of the global environment, transpires alongside natural climate cycles. According to Dogan and Seker (2016), the presence of carbon dioxide emissions poses a significant obstacle to both foreign direct investment and the achievement of environmental sustainability in emerging nations. According to a study by Sheoran et al. (2018), air pollution and the negative effects of industrial waste flows are exacerbating environmental degradation in Asian economies. Free trade liberalization and foreign direct investment (FDI) are a subset of the several elements that have the potential to foster economic growth and development. A number of the above-described causes present a potential long-term threat to our capacity to sustain our natural resources (Dogan & Seker, 2016). Moreover, carbon dioxide (CO_2) serves as the primary contributor to greenhouse gas emissions, and historically, it has been a costly factor to consider. The causes of environmental deterioration and economic globalization are multifaceted (Çetin & Ecevit, 2015). The relationship between per capita GDP and environmental quality is influenced by the positive impact of increased financial growth, as demonstrated by Al-Mulali and Ozturk (2015). The interconnection lies in the correlation between economic growth and the allocation of financial resources. The augmentation of commercial and economic activity yields various consequences for mitigating global warming. There are several strategies available to reduce greenhouse gas emissions. According to recent research findings, a number of Asian nations have witnessed a notable rise in several factors, including energy consumption, GDP growth, industrialization, foreign direct investment, and carbon dioxide emissions (Bekhet & Othman, 2017; Salahuddin et al., 2018; Sasana & Aminata, 2019).

The success of economic development initiatives, particularly those centered around financing infrastructure and industrial projects, is heavily dependent on the accessibility of external borrowing options. There is a potential for an escalation in carbon dioxide (CO_2) emissions due to nations augmenting their economic output and industrial production, hence resorting to borrowing as a means to finance these endeavors. The substantial rise in the utilization of fossil fuels, stemming from the swift process of industrialization and economic expansion, constitutes a significant factor in the escalation of energy consumption levels and the release of greenhouse gases into the atmosphere (United Nations, 2019). There exists a significant correlation between a country's energy mix and the quantity of carbon dioxide (CO_2) it emits. It is anticipated that the utilization of foreign debt with the intention of developing and harnessing fossil fuel resources, including coal, oil, and natural gas, will have a substantial impact on the emission of carbon dioxide (CO_2). Nevertheless, the utilization of debt as a means to finance investments in renewable energy projects or clean technology may result in a comparatively smaller impact on emissions. Nations characterized by significant levels of foreign debt may have

a need to prioritize economic expansion and debt servicing, perhaps resulting in the relaxation of environmental regulations and diminished enforcement endeavors. These events have the potential to lead to less stringent regulations on emissions, thereby contributing to an increase in atmospheric CO_2 levels (EESI, 2021). The extent of a country's external debt may potentially limit its ability to allocate funds for sustainable development and climate change mitigation. In instances where debt repayment becomes challenging, governments may opt to allocate priority to commercially advantageous projects that can be expeditiously financed, irrespective of their environmental ramifications. Climate finance efforts have the potential to mitigate carbon dioxide emissions through the utilization of external loans to fund these initiatives. The impact of borrowing funds exhibits heterogeneity among countries, introducing intricacy into the dynamics among these three systems. In order to attain a sustainable future, it is imperative to emphasize economic growth, responsible debt management, and environmental conservation. Simultaneously, while effectively managing their nations' foreign debt (Khan et al., 2020; Kumar, 2020; Wang et al., 2022), it is imperative for governments to accord priority to the adoption of ecologically friendly technologies, the implementation of energy-saving measures, and the pursuit of climate resilience initiatives.

The global recognition of the importance of mitigating climate change has led to a notable increase in efforts worldwide to reduce carbon dioxide emissions. The Kyoto Protocol addresses the issue of climate change through the implementation of carbon offsetting programs such as the Clean Development Mechanism and Joint Implementation. The implementation of the carbon trade system is crucial for the attainment of these objectives. It is imperative for the global community to collaborate in order to address the issue of climate change. The mitigation of climate change necessitates a significant allocation of official development assistance (ODA). According to Kang (2009), poor nations are expected to experience the impacts of climate change to a greater extent compared to wealthier nations due to their shorter response times and higher dependence on businesses that contribute to environmental pollution. According to Michaelowa and Michaelowa (2007), the shifting priorities of official development assistance (ODA) are being influenced by climate change. The suggestion was put forward in 2009 by the Organization for Economic Co-operation and Development (OECD). Nevertheless, there is a limited body of evidence that establishes a connection between official development assistance (ODA) and climate change. There are three main factors that significantly influence international capital flows, according to research by Driffield and Jones (2013). These factors include foreign direct investment (FDI), official development assistance (ODA), and migrant remittances. Official Development Assistance (ODA) plays a crucial role in promoting economic growth in impoverished nations by facilitating the influx of foreign money. An extensive study has been conducted to examine the impact of official development assistance (ODA) on the economic growth of disadvantaged nations (Siraj, 2012). According to the research conducted by Burnside and Dollar (2000), the implementation of appropriate policies can potentially stimulate economic growth in a recipient nation through the inflow of foreign capital via official development assistance (ODA) initiatives. However, scholars in the discipline, like Griffin and Enos (1970), have expressed concerns regarding the potential hindrance to economic advancement by ODA and other forms of foreign assistance. Momita et al., (2019) argue that while examining the effectiveness of official development assistance (ODA), it is essential for researchers to consider the diverse nature of ODA. The economic growth of the recipient country may be significantly influenced by the quality of official development assistance (ODA).

In their study, Bese et al. (2021) employ the environmental Kuznets curve (EKC) hypothesis to examine the relationship between China's carbon dioxide (CO_2) emissions and its external debt. The use of external debt is associated with a significant improvement in emissions quality. The impact of EMS on the process of maturation exhibits variability. China's empirical support for the Environmental Kuznets Curve (EKC) remains insufficient. The findings align with the observed trends in the Chinese economy. The Republic of Turkey possesses a considerable magnitude of external debt, which has been subject to investigation by Katircioglu

and Celebi (2018) in order to analyze the implications of this particular circumstance. The findings of this study provide empirical evidence supporting the presence of an Environmental Kuznets Curve (EKC) phenomenon in Turkey. The findings of this study suggest that there is no significant relationship between Turkey's overall foreign debt and its long-term Environmental Kuznets Curve (EKC) performance. Bachegour and Qafas (2023) employed the environmental Kuznets theory as a framework to examine the association between national debt and carbon dioxide emissions. The aim of this study is to utilize an autoregressive distributed lag (ARDL) model to examine the enduring and immediate consequences of the escalating foreign debt of Morocco on carbon dioxide emissions, considering the nation's significant reliance on fossil fuels. The main results validate the presence of a Kuznets curve with an inverted U-shape and provide evidence of a substantial influence of foreign debt on CO_2 levels in Morocco. The findings of this analysis demonstrate a negative U-shaped association between carbon dioxide (CO_2) emissions and external debt. Although the ecological footprint per capita does not exhibit an inverse causal relationship, such a relationship does exist between foreign debt and economic development. According to Beşe and Friday (2022), there is a positive correlation between increasing prosperity and individual carbon emissions over time. The authors also suggest that there is a correlation between external debt and emissions. Akam et al., (2021) conducted a comprehensive analysis of the relationship between foreign debt, economic development, energy consumption, and carbon emissions in a sample of 33 highly indebted poor countries (HIPCs) spanning the period from 1990 to 2015. Based on the research findings, there is a positive correlation between economic growth and the increase in levels of pollution. Furthermore, it is evident that the magnitude of a nation's external debt exerts a substantial influence on its carbon dioxide (CO_2) emissions. On the contrary, the utilization of renewable energy sources has been proven to be an effective approach to promoting environmental cleanliness by reducing carbon dioxide (CO_2) emissions.

The focus of Kablan and Chouard (2022) study was on carbon dioxide emissions in aid-receiving countries. An econometric study has demonstrated that the provision of climate aid specifically designated for renewable energy sources has the potential to effectively mitigate CO_2 emissions. However, it is important to note that this outcome is contingent upon the fulfillment of a specific threshold. It is improbable, nevertheless, that this favorable consequence will endure indefinitely. The implementation of a carbon tax represents a potential strategy for mitigating carbon dioxide emissions in underdeveloped nations, where the prioritization of economic efficiency frequently supersedes environmental considerations. Ultimately, the results indicate that the utilization of foreign eco-technologies does not effectively mitigate carbon dioxide emissions or diminish their scale. The study conducted by Arvin et al. (2022) examined the relationship between development assistance and institutional quality in relation to carbon dioxide (CO_2) emissions in developing and middle-income nations. The study employed Vector Error Correction Model (VECM) techniques to elucidate the intricate relationships among all variables within the given time constraints. The analysis of Granger causality has uncovered a significant correlation between foreign aid and the long-term enhancement of institutional quality and reduction of greenhouse gas emissions. The study conducted by Boly (2018) used an empirical approach to investigate the relationship between development aid and carbon dioxide (CO_2) emissions in countries with low- and middle-income levels. Empirical evidence indicates a positive association between multilateral assistance and reduced pollution levels; however, bilateral aid does not exhibit any discernible impact. This implies that the effectiveness of aid varies depending on the type of donor. Nevertheless, the outcomes of bilateral aid specifically designated for environmental protection possess the capacity to be significantly more substantial. In order to effectively mitigate pollution levels, it is widely recognized that substantial volumes of bilateral environmental assistance are necessary. This is the reason why one cannot only predict a linear outcome.

II. METHOD

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The IPAT model serves as the fundamental theoretical framework around which our whole foundation is built. The IPAT model was developed with the objective of identifying the primary factors contributing to environmental degradation. When examining a given phenomenon, it is important to consider many factors, such as the size of the population, the amount of influence, and the degree of technical proficiency. The decomposition equation, as outlined in the model proposed by Ehrlich and Holdren (1971), utilizes equation (1).

$$\mathbf{I = PAT} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (\mathbf{1})$$

The entire environmental impact (I), the total human population (P), the influence (A), and technological advancement (T). In their study, York et al., (2003) extensively examine the limitations of the IPAT paradigm. When a known component of an equation is provided, the remaining components can be computed with relative ease and a minimal margin of error. The IPAT model is subject to limitations due to its reliance on a deterministic approach to assessment. The Stochastic Impacts via Regression on Population, Influence, and Technology (STIRPAT) methodology was developed by Dietz and Rosa (1997) as a means of estimating the IPAT model. To illustrate the application of this methodology, let us examine Equation 2.

$$\boldsymbol{I_{it} = \alpha\, P_{it}^{\beta} A_{it}^{\Upsilon} T_{it}^{\Psi} e_{it}} \quad \ldots\ldots\ldots\ldots\ldots \quad (\mathbf{2})$$

The primary alphanumeric symbols, such as α, β, $\boldsymbol{\Upsilon}$, and $\boldsymbol{\Psi}$, utilized in the coefficients represent the respective significant explanatory variables. The term "eit" is employed to denote the existence of a stochastic error. The STIRPAT model employs a stochastic approximation of the IPAT model in order to quantify the impact of individual changes on environmental conditions. In our analysis, official development assistance (ODA) and external debt (ED) were employed as proxies for real technological advancement. Consequently, the model that has been resolved in this study can be denoted as (3). The estimation of CO_2 emissions can be influenced by several variables, including official development assistance (ODA), external debt (ED), population (P), and gross domestic product (GDP), as indicated in the aforementioned equation. The utilization of the natural logarithm transformation is employed in the linear regression model outlined in Equation (3), as demonstrated in Equation (4).

$$\mathbf{CO_{2it} = \alpha \left(P_{it}^{\beta}\right)\left(A_{it}^{\Upsilon}\right)\left(T_{it}^{\Psi}\right)\left(e_{it}\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (\mathbf{3})$$

After taking natural log both sides,

$$\mathbf{CO_{2it} = \alpha + \beta(P_{it}) + \Upsilon(GDP_{it}) + \Psi(ODA_{it}) + \lambda(ED_{it}) + (e_{it})} \quad \ldots\ldots\ldots\ldots \quad (\mathbf{4})$$

Consequently, a hypothesis was formulated positing a relationship between carbon dioxide (CO_2) emissions and many factors, including population (P), gross domestic product (GDP), official development assistance (ODA), and external debt (ED). Our research is centered on the Asian countries of Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka. The dataset utilized in this study was sourced from the World Bank's comprehensive repository of development indicators, commonly referred to as the World Development Indicators (WDI) database. The dataset spans from 1990 to 2019.

Table 1 Panel Unit Root Results

Summary Results										
	Levin, Lin & Chu		Breitung t-stat		Im, Pesaran and Shin W-stat		ADF - Fisher Chi-square		PP - Fisher Chi-square	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
CO_2	0.29	0.00	0.14	0.00	0.18	0.00	0.18	0.00	0.13	0.00
ED	0.53	0.00	0.29	0.68	0.89	0.02	0.44	0.00	0.98	0.00
GDP	0.95	0.00	0.99	0.00	0.96	0.00	0.78	0.00	0.95	0.00
NODA	0.00	0.00	0.13	0.00	0.03	0.00	0.07	0.00	0.09	0.00
POP	1.00	0.95	0.06	0.01	1.00	0.38	0.99	0.00	0.75	0.03

Source: All above observations are calculated through Eviews 12

Notes: POP represent total population, ED is external debt, CO_2 is carbon dioxide emission, NODA is net official development assistance, and GDP is gross domestic product.

Table 2 Panel Cointegration Results

Cointegration by Kao Test		
	t-statistics	Probability
ADF	-2.9533	0.0016
Residual Variance	0.001844	
HAC Variance	0.002430	
Cointegration by Trace and Max-Eigen (Fisher) Tests		
Hypothesized	Fisher Stats (Trace Test)	Fisher Stat (Max-Eigen test)
None	106.2 (0.0000)	49.99 (0.0000)
At most 1	65.82 (0.0000)	34.69 (0.0005)
At most 2	39.64 (0.0001)	22.57 (0.0316)
At most 3	27.91 (0.0057)	22.68 (0.0306)
At most 4	25.17 (0.0140)	25.17 (0.0140)

Table 3 VECM Estimates

Long-run Results		
Variables	Coefficients/t-statistics	
EDS	-2.6144 (2.3605)*	C = -6.8788
GDP	4.8916 (3.5261)*	
NODA	-2.4420 (3.3755)*	
Population	-0.8359 (1.2739)	
Short-run Results		
Variables	Coefficients/t-statistics	
CointEq.	-0.01959 (3.0432)*	R^2 = 0.3165
EDS	-0.1507 (1.4937)	F-Statistics = 1.5686
GDP	-0.1917 (1.6874)	
NODA	-0.0166 (0.5280)	C = 0.0435 (2.3612)*
Population	-0.02092 (0.0209)	
"*" representing the significance and probability value less than 0.05 (5%).		

III. RESULTS AND DISCUSSIONS

In order to ascertain that the panel is not affected by unit-root skewness, a series of tests are conducted. These tests include the Levin, Lin, and Chu test, the Breitung t-stat, the Im, Pearson, and Shin W-stat, the ADF-Fisher Chi-square, and the PP-Fisher chi-square. Based on a

series of tests, it has been established that our data exhibits stationarity at the first difference, denoted as I(1). Consequently, the utilization of the Vector Error Correction Model (VECM) econometric approach is warranted. Table 1 displays the calculated unit roots.

The table 2 presented above provides a summary of the results obtained from three commonly employed cointegration tests, namely the Kao test, the trace test, and the max-eigenvalue test. These tests were conducted on a panel dataset. The co-integration of all variables is evidenced by the findings obtained from all three methodologies. A vector error correction model (VECM) is employed for both the short- and long-term analyses due to the presence of cointegration among all the variables.

Table 3 categorizes the outcomes into long-term and short-term classifications. Both the external debt stock (EDS) and the net official development assistance (NODA) exhibit a statistically significant and negative impact on carbon dioxide (CO_2) emissions over an extended period of time. The results indicate that there is a decrease in carbon dioxide (CO_2) emissions of 2.614% and 2.442% for each incremental rise in EDS and NODA, respectively. The analysis suggests that a one-unit rise in GDP is associated with a 4.8916-unit increase in CO_2 emissions, indicating a statistically significant positive correlation between these two variables. The data indicates that there is a positive correlation between population and CO_2 emissions in South Asian countries from 1990 to 2019. However, this correlation is shown to be statistically insignificant. The empirical analysis reveals that the impact of external debt stock (EDS), gross domestic product (GDP), net official development assistance (NODA), and population on carbon dioxide (CO_2) emissions in South Asian nations during the period from 1990 to 2019 is characterized by a lack of statistical significance and a negative direction of influence.

IV. CONCLUSIONS

The objective of this study was to analyse the influence of gross domestic product (GDP), population (P), external debt stock (EDS), and net official development assistance (NODA) on carbon dioxide (CO_2) emissions in Asian economies during the period spanning from 1990 to 2019. This study uses different econometric methods, such as unit-root testing, panel cointegration approaches, and the vector error correction model (VECM), to look at the short-term and long-term effects. Empirical analyses have verified the presence of a significant and adverse relationship between long-term CO_2 emissions, net official development assistance, and external debt. This study provides support for the proposition that the escalation of external debt and net official development assistance (aid) has a causal effect on the reduction of carbon dioxide emissions in Asian economies. There is also evidence suggesting a positive correlation between increasing GDP and the emission of carbon dioxide into the Earth's atmosphere. The analysis reveals that there is a statistically significant association between population and CO_2 emissions in Asian economies throughout the period spanning from 1990 to 2019. However, it is important to note that this relationship lacks statistical significance. The short-term timeframe from 1990 to 2019 revealed that there was no significant negative impact of external debt, net official development assistance, GDP, or population on CO_2 levels in Asian economies.

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