THE ROLE OF DIGITAL TECHNOLOGY AND SUSTAINABLE ENERGY IN MITIGATING ENVIRONMENTAL DEGRADATION: A PATH TO ACHIEVING SDGS FOR SOUTH EAST ASIAN ECONOMIES

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Abstract

This research study examined the role of sustainable energy and digital technology in reducing environmental degradation, with a key focus on attaining the Sustainable Development Goals (SDGs) for South East Asian Economies. The study also examines the presence of the Environmental Kuznets Curve (EKC) hypothesis in the selected economies. The study will collect a panel dataset for the selected economies from 2000 to 2024. The study will apply some prerequisite diagnostic tests, such as unit root tests, descriptive statistics, VIF, and correlation analysis, to check the properties of the dataset. Furthermore, the study will use advanced econometric techniques called Generalized Method of Moments (GMM) for investigating the relationship between variables. The literature review section highlights the key trends and the potential of digital technologies and renewable energy (RE) in promoting environmental sustainability, as well as some studies on reducing environmental degradation. The study aims to investigate how these solutions can effectively mitigate environmental impacts. The findings of this study will be helpful for policymakers, investors, industries, and strategic planners in order to build an ecosystem for green technology and sustainable development. More broadly, this work highlights the importance of cross-sectoral collaboration in utilizing technologies and renewable resources to meet environmental goals for the economies. Through harmonizing economic development with environmental conservation, Southeast Asia can show the world the path to a more sustainable future.

Keywords: digital technology, sustainable energy, industrialization, Southeast Asian economies, SDGs.

Introduction

The Sustainable Development Goals (SDGs) are 17 global standards that focus particularly on society, the economy, and the environment. The United Nations (UN) emphasized that the business community had a vital role to play in achieving these targets while concurrently urging that governments from developed and developing countries must make their own plans for achieving these goals (Jones, et al., 2017; Xiao, et al., 2025). For this target, countries around the world need to work together in order to achieve their particular objectives and improve their standard of living, and make their environment cleaner and greener.

As we are living in the fourth industrial revolution, with the increasing use of digital technology, its integration and its complex relationships with broader economic and environmental concerns have drawn much attention from academics and practitioners around the globe (Jin & Yu, 2024). Digital technology is also referred to as information and communication technology (ICT) (Özkan, et al., 2024). ICT is widely recognized as a

multifaceted tool that helps in addressing the global concerns listed in the SDGs. Similar to this, the International Telecommunication Union (ITU, 2020) has acknowledged ICT as a vital innovation facilitator in the achievement of global SDGs. Through effective use of ICT and global connectivity, emerging economies can acquire information and knowledge, hence enhancing their competitive advantage through technology spillovers (Saleem & Xu, 2025; Jin, et al., 2022).

Since the early 21st century, climate change and global warming become increasingly important concerns for governments, policymakers, and both industrialized and developing countries (Udeagha & Breitenbach, 2023). A wide consensus exists that the dramatic increase in greenhouse gas emissions, particularly CO2 emissions, is the primary cause of environmental change (Anser, et al., 2021). Reports indicate that the widespread reliance on polluting energy sources contributes to a 1.9% annual increase in CO2 emission. Therefore, scholars around the world have focused on identifying the crucial factors that affect energy consumption and release of carbon dioxide, with the objective of aiding assist policymakers in formulating effective policies to mitigate global warming. Because institutional financing for private investors has the potential to stimulate long-term economy expansion, financial development (FD) and economic growth (GDP) are inherently interconnected. Since financial intermediation is crucial to improving environmental sustainability, a trustworthy financial institution plays a vital role in fostering this endeavor by RE projects (Jinqiao, et al., 2022; Saleem et al., 2024). Long et al. (2015) claim that there is a method for reducing CO2 emissions that makes use of RE. This is because the ecosystem is severely strained by the overuse of non-renewable resources. The way economies are constructed around energy sources, including RE, is evolving, claim Khan, et al. (2020). FD promotes long-term GDP. However, FD may have either a favorable or negative impact on CO2 emissions. Zhang (2011) concludes that GDP propelled by FD tends to raise CO2 emissions. Research Objectives

- To examine the impact of digital technology on environmental degradation and to characterize the inherent the nature of their relationship.
- To analyze the relationship between the adoption of renewable energy sources and environmental degradation, with a specific focus on understanding its effect.
- To evaluate the influence of economic growth on environmental degradation, with a special emphasis on identifying any noticeable positive correlations.
- To explore how financial development affects environmental degradation and determine the characteristics of this relationship.

Scope of the Research

Population Scope

Southeast Asian nations, particularly Malaysia, as well as other economies in the region that are rapidly industrializing and urbanizing, are the main focus of this study. The study takes into account economic activity, technological developments, and policies that are pertinent to these groups and how they affect environmental sustainability.

Variable Scope

The study examines several important factors, including the use of RE, the acceptance of digital technologies, FD, and GDP. Within the framework of regional development and sustainability initiatives, it investigates the connections between these factors and their combined impact on environmental deterioration.

Time Scope

This research study used the latest data for analysis, actually the study used annual panel data collected from various sources from 2000 to 2024, which are covered in the analysis. The significant advancements in digital technologies, RE initiatives, and policy frameworks aligned with the SDGs collectively provide a contemporary and highly relevant perspective on fostering sustainable growth and ensuring environmental preservation.

Literature Review

Effect of Digital Technology on the Environment Degradation

There are two schools of thought when we discuss the function of digital technology. According to one viewpoint, digital technology helps industrialization, which will eventually help in increasing GDP. The opposing viewpoint, on the other hand, emphasizes its detrimental effects by arguing that increased industrialization leads to worsening environmental conditions due to increased energy consumption. Shobande and Asongu (2023) investigated the connection between ICT and environmental sustainability. Their findings showed that ICT has positively contributed to environmental sustainability. Khan, et al. (2022) employed a panel data technique, including generalized least squares and cointegration analysis, to study how ICT, innovation, and the use of RE affected CO2 emissions across BRICS countries between 1990 and 2019. Their results revealed that CO2 emissions along with GDP and FD are negatively impacted by two ICT indicators: mobile cellular subscriptions and fixed broadband subscriptions. Additionally, their study provided support for the EKC concept. Batool, et al. (2022) conducted an analysis on the impacts of ICT, RE use, and FD on the release of carbon dioxide in several East and South Asian emerging nations. The findings imply that both ICT and FD exert a long-term beneficial influence on mitigating environmental deterioration. Additionally, their research indicated that GDP affects CO2 emissions positively, yet squared GDP leads to a reduction of CO2 emissions. This phenomenon supports the inverted U-shaped EKC theory. The study first hypothesis statement is:

H_1: There is a significant negative relationship between digital technology and environmental degradation.

Effect of Renewable energy on the Environment Degradation

Chen et al. (2023) examined how China's release of CO2 was affected by RE and non-RE sources. Granger causality analysis was used in the study to investigate the association between the amount of air pollution and energy sources utilizing a large dataset of macroeconomic and energy-related data from China from 1990 to 2022. According to the research, there is a unidirectional relationship between air pollution and both renewable and non-RE sources. Batool, et al. (2022) examined the effect of RE consumption on fossil fuel consumption through panel data covering the years 1985–2020. Their findings showed that the adoption of RE has a favorable influence on environmental quality. Chen, et al. (2022) explored the nonlinear effects of RE, non-RE, and GDP on the release of CO2 per capita using panel data from 97 countries between 1995 and 2015. The results of the stud revealed a negative correlation between consumption of RE and CO2 emissions. The results underscore that rising RE consumption will only lead to a reduction in per capita CO2 emissions once a nation attains a specific threshold of RE consumption. The second hypothesis statement of this study is:

H_2: There is a significant negative relationship between renewable energy and environmental degradation

Financial Development and Environmental Degradation

FD could give industries the financial support they need to use greener and less polluting technology to enhance the environment. Foreign investment may be drawn to FD, leading to a rise in R&D projects that use cutting-edge technology for environmental improvement. Anwar, et al. (2022) investigated the effects of GDP, agriculture, urbanization, FD, and RE use on CO2 emissions across fifteen Asian economies between 1990 and 2014. Their empirical findings indicated that urbanization, FD, and GDP all contributed to the increased release of CO2 in the atmosphere. Similarly, Shoaib, et al. (2020) aimed to explore the relationships between FD and the release of CO2 in G8 and D8 countries from 1999 to 2013. They found that FD had a long-term statistically significant and positive impact on greenhouse gas emissions in both groups of countries. Likewise, Adebayo, et al. (2023) examined the effects of FD on CO2 emissions in the MINT countries (Mexico, Indonesia, Nigeria, and Turkey) by using annual data from 1969 to 2019. Their results show a unidirectional causal relationship between FD and CO2 emissions. Udeagha and Breitenbach (2023) investigated the direct and indirect effects of FD on CO2 emissions in South Africa between 1960 and 2020 by using the EKC framework. Their findings demonstrated that FD led to a reduction in the release of CO2 in both the short and long term, providing further evidence supporting the applicability of the EKC theory to South Africa. The third hypothesis statement is:

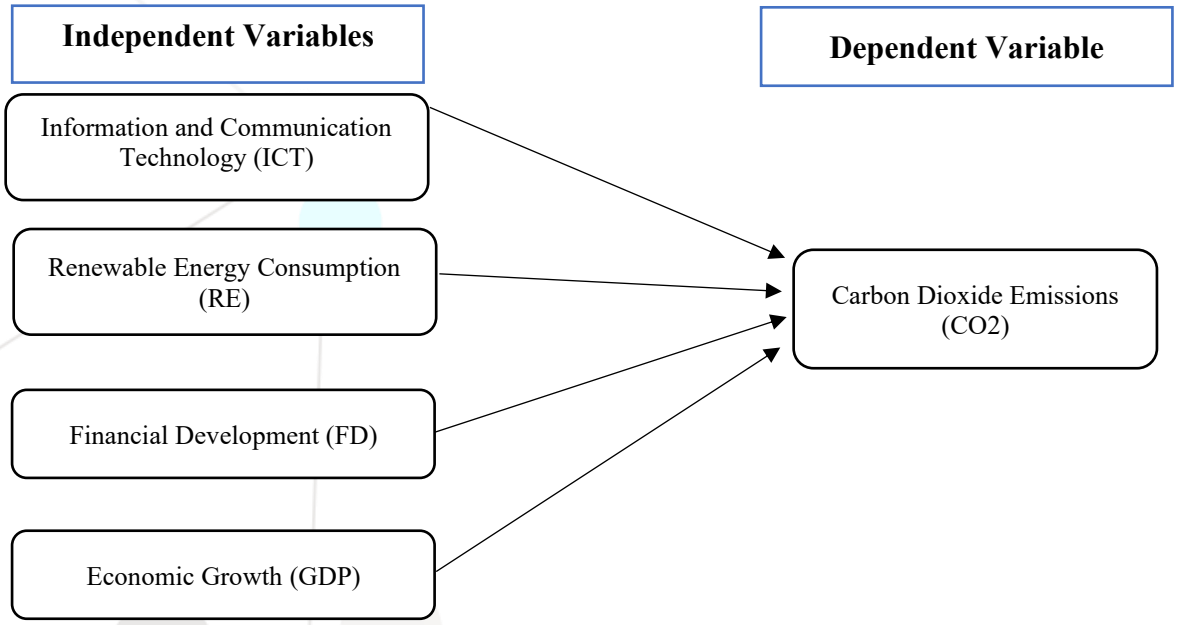
H_3: There is a significant positive/negative relationship between economic growth and environmental degradation

Impact of economic growth on Environment Degradation

Numerous empirical studies have examined the EKC theory with varying degrees of success. Raihan, et al. (2023) examined the dynamic influences of GDP, RE consumption, and tourism on the release of CO2 in Egypt. Time series data from 1990 to 2019 were used, and the empirical results showed that although tourism, the use of fossil fuel energy, and GDP all contribute to cumulative CO2 emissions. Ayhan, et al. (2023) looked at the relationship between GDP and energy consumption and CO2 emissions in the G-7. This study used quantile-on-quantile regression (QQR) as the foundational model to analyze the yearly data from 1997 to 2021. The empirical findings generally indicate that economic expansion tends to increase CO2 emissions. However, specifically for Japan, France, and Germany, GDP exhibited a nuanced effect. These countries have reducing effects at lower quantiles, decreasing effects at middle quantiles, and decreasing effects at higher quantiles. Onofrei, et al. (2022) investigated the dynamics of the relationship between economic development and CO2 emissions across the 27 EU member states from 2000 to 2017. Their findings show a significant association between GDP and the release of carbon dioxide in the atmosphere. On average, a 1% change in GDP corresponds to a 0.072% change in CO2 emissions. Furthermore, the results of the cointegration technique suggested the presence of a long-run cointegrating association between GDP and CO2 emissions within EU countries. The fourth hypothesis statement is:

H_4: There is a significant positive/negative relationship between financial development and environmental degradation

Research Framework



Research Methodology

This study is planned to evaluate the impact of Information and Communication Technology (ICT), renewable energy (RE), financial development (FD), and economic growth (GDP) on Carbon dioxide emissions (CO2) among South East Asian countries. The data collection is mainly from secondary sources. The sample countries for this study are Malaysia, Indonesia, Thailand, Singapore, Vietnam, Philippines, Myanmar, Cambodia, Brunei, Laos, and Timor Leste. The renowned Environmental Kuznets Curve (EKC) theory, however, offers an alternate perspective, suggesting that environmental quality may improve as economic growth reaches a certain threshold. A panel dataset that ranges from 2000 to 2024 will be employed. Table 1 presents detailed measurements of the variables and data sources.

Table 1 Variables Description

Variable	Description	Source
Carbon Dioxide Emissions (CO2)	Carbon Dioxide (Metric Ton per capita oil equivalent)	WDI
Information and Communication Technology (ICT)	Individual using the internet (% of the population)	WDI
Renewable Energy Consumption (RE)	Renewable energy consumption (% of total final energy consumption)	WDI
Financial Development (FD)	Financial Development Index	IMF
Economic Growth (GDP)	Gross Domestic Product per capita (constant 2015 US$)	WDI

Model Specification

The EKC theory posits a nonlinear association between economic prosperity and environmental pollution. An initial positive association exists between income levels and environmental degradation during the early growth stages of GDP. However, constant economic expansion fosters technological advancements and shifts the composition of total output, increasing the proportion attributable to the service sector relative to the production sector. In response to these structural adjustments, the overall ecological system tends toimprove, leading to an inverse the relationship between pollution and income (Wang et al., 2020). For Model 1 that specified by respective Eq. (1), $\ln CO2 - Ems$ denotes carbon emissions, lnGDP and $\ln GDP^2$ denote the real GDP per capita and its square term, respectively. The remaining variables include ICT, FD, and RE, respectively.

$$lnCO2 - Ems_{it} = \alpha_0 + \alpha_1 lnGDP_{it} + \alpha_2 lnGDP_{it}^2 + \alpha_3 lnICT_{it} + \alpha_4 lnFD_{it} + \alpha_5 lnRE_{it} + \mu_{it} \quad (1)$$

In equation (1) that represents Model 1, the subscripts represent the cross-sectional (i) and time (t) elements of the variables. $\alpha_1 - \alpha_5$ are coefficient estimates, α_0 constant term, and μ_{it} is the white-noise term.

The correlation between GDP and CO2 can manifest in several ways: if α_1=α_2= 0, there is no relationship; if α_1> 0 and α_2= 0, a positive monotonic relationship exists; if α_1< 0, α_2= 0, a negative monotonic relationship is present; if α_1> 0, α_2< 0, an inverted U-shaped relationship is observed; and if α_1< 0, α_2> 0, a U-shaped relationship is evident. Additionally, the positive and significant α_1, along with the negative and significant α_2, substantiates the validity of the EKC hypothesis. The negative and significant coefficients associated with α_3, α_4, and α_5, indicate that ICT, FD, and RE, respectively, can contribute to the reduction of CO2 emissions.

Implications of the Study

For policymakers, business executives, and other stakeholders in Southeast Asian economies looking to advance sustainable development, this research offers insightful information. The results emphasize how crucial it is to combine digital technologies and RE sources as tactical instruments to slow down environmental deterioration and help achieve the SDGs. These insights can be used by policymakers to create focused policies and programs that support digital transformation, sustainable energy deployment, and green innovation.

The study highlights the possible financial gains for industry participants from implementing ecologically friendly procedures, encouraging creativity, and making investments in digital infrastructure and RE. It also emphasizes how important green finance and FD are to encouraging sustainable investments.

Additionally, by synthesizing current understanding of the connections between digital technology, RE, GDP, and environmental sustainability, the research advances scholarly discourse. It provides a starting point for upcoming empirical research and policy analysis that aims to create all-encompassing plans for the region's environmental preservation.

In order to harness technological advancements and sustainable energy solutions and promote resilient and environmentally friendly GDP, this study ultimately calls for a cooperative approach among governments, corporations, and communities. The knowledge gained from this study can direct successful programs and policies to build a sustainable and ecologically aware Southeast Asia.

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