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Do Financial Regulation and Technology Matter in Fostering Green Growth?

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Abstract

Effective regulation and technological innovation are key factors in driving the implementation of green growth initiatives. This research investigates how financial regulation and technological innovation influence green growth, proxied by carbon productivity, with data from 1996 to 2020 across ASEAN-5 Countries. A Panel Dynamic Ordinary Least Square (DOLS) model is conducted to analyze the long-run effect on each variable. The result showed that financial regulation, proxied by regulatory quality and economic freedom, positively and significantly influences green growth. Meanwhile, technological innovation has a positive but not significant influence on green growth. According to the findings, this study proposes adopting top-tier regulations and a step-by-step approach to realizing green growth. Meanwhile, the government can also open an investment as funding to improve innovation in green technology.

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INTRODUCTION

Economic development disregarding environmental aspects primarily contributes to increased environmental degradation. This is evidenced by a 57.71% rise in CO2 emissions in 2020 compared to 1990 (World Bank, 2023). Moreover, the Earth's surface temperature has increased by one °C due to CO2 emissions since 1880 (NASA, 2023). Furthermore, massive environmental damage can lead to negative externalities for life on Earth. Research from the Global Burden of Disease indicates that deaths attributable to air pollution have reached 6.67 million (Murray et al., 2020). Sustainable CO2 emissions production is projected to increase the Earth's surface temperature by up to 4.5°C by 2100 (Meinshausen et al., 2011). Consequently, implementing sustainable and environmentally friendly economic development is crucial for the sustainability of life on Earth.

Environmental degradation poses a significant challenge for many countries, particularly within the ASEAN region. ASEAN currently contributes 6.87% of global greenhouse gas emissions (Climate Watch, 2022). The demand for fossil energy in ASEAN countries reaches 90%, driving it to become the fuel of economies (IEA, 2023). Consequently, CO2 emissions grow at 3.8% per year, with the most significant contributions coming from Indonesia, the Philippines, and Thailand (ASEAN, 2022; IEA - International Energy Agency, 2023). Click or tap here to enter text. This has detrimental effects on life in ASEAN countries, as evidenced by the increasing number of natural disasters, rising temperatures, crop failures, and the spread of diseases (ASEAN, 2022).

Sustainable economic development is essential to address ongoing environmental degradation. Therefore, the OECD introduces the concept of green growth, aiming to promote economic growth while maintaining the availability of natural resources and environmental sustainability for all living beings (OECD, 2023). This can be achieved by providing inclusive opportunities for everyone through driving innovation and investment based on sustainable development (OECD, 2023). Economists also argue that green growth is a solution to enhance environmentally friendly economic growth (Hao et al., 2021). Through green growth, the transition to sustainable economic development can be achieved at low cost, efficiently, and affordably if consistently pursued, viewed optimistically socially and politically, and flexible according to the country's conditions (World Bank, 2012).

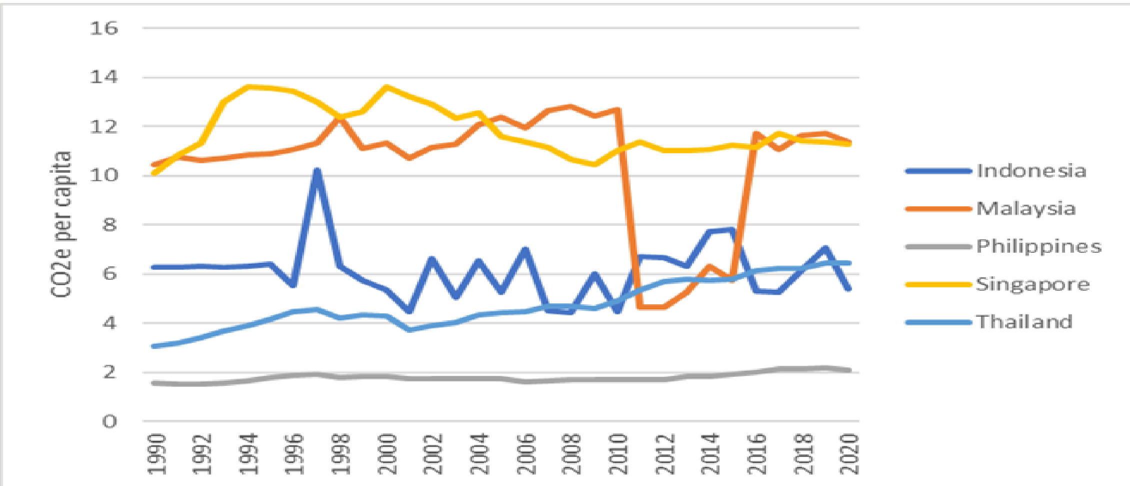

Figure 1. CO2 Emission Per Capita Production in ASEAN-5
Source: Climate Watch, 2022 (Processed)

The realization of the green growth concept heavily relies on government regulations and policy directions. Environmentally oriented-governance with high-quality institutions can effectively drive green growth (Degbedji et al., 2024; Dong & Ullah, 2023). Tightening environmental regulations can minimize ecological damage (Wu et al., 2019). Fiscal policies also play a significant role in environmental conditions (Ma et al., 2023). However, these regulations and policies must also consider the country's conditions. This implies that rules and guidelines should simultaneously enhance economic growth and environmental quality. Therefore, implementing green growth should involve local resources, including human resources, local products, research and innovation, and investments.

Research and technological innovation play a crucial role in accelerating the realization of green growth. Proficient innovation and technology can create solutions that reduce waste generated during production. This is evidenced by research (Mohd Suki et al., 2022) showing that technological innovation can reduce CO2 emissions levels in ASEAN countries. Through environmentally friendly technology, economic growth can be pursued while minimizing environmental damage. Therefore, technological innovation is also a crucial factor in achieving green growth.

This research aims to identify the influence of financial regulation and technological innovation on green growth contribution. However, the estimation of these two variables alone is insufficient. Therefore, we consider the macroeconomic variables as control variables, which include inflation, foreign direct investment, and government expenditure. The study by Shpak et al. (2022) and Weber, 2024) has shown that inflation contributes to minimizing CO2 emissions. Furthermore, Foreign direct investment has two types of influence, which are a positive influence on environmental degradation (Tabash et al., 2023; Yilanci et al., 2023) and a negative influence on environmental degradation (Ozkan et al., 2023; Rahaman et al., 2022). Then, government expenditure positively impacts green growth (Cigu et al., 2020).

Many researchers have extensively discussed environmental research, but studies on the impact of financial regulations and technological innovation on green growth still need to be conducted in the ASEAN region. Previous research on green growth has primarily focused on the China region (Fan et al., 2021; Hou et al., 2023; Li & Wang, 2019; Meng & Niu, 2012; Yao et al., 2023), with only one study conducted in ASEAN (Mohd Suki et al., 2022). Furthermore, only a few studies (Cigu et al., 2020; Odugbesan et al., 2021) have addressed the impact of financial regulations on green growth.

The findings are crucial to promoting sustainable economic development in the ASEAN region. Examining the impact of financial regulation and technological innovation can provide a comprehensive understanding of how these factors contribute to green growth to support sustainable development in ASEAN. Odugbesan et al. (2021) state that financial regulation is formed by economic freedom and good governance indicators. A country with high economic freedom will boost the economy and attract investors to environmentally friendly businesses contributing to economic development. Furthermore, regulations derived from good governance will mitigate the potential for companies that are not environmentally friendly. Other than that, Cigu et al. (2020) also stated that financial regulation is necessary to ensure the optimal provision of financing and financial services to the real economy and society while maintaining the stability and liquidity of the financial sector and preserving public trust in financial markets. Therefore, financial regulation is essential to maximize green growth.

The hypothesis of this research is drawn from the previous research and the concept of green growth itself. Green growth aims to identify aspects of economic and environmental policy that reinforce each other and synergize with the inclusiveness agenda (OECD, 2023). Green growth is proxied by carbon productivity, calculated as GDP/CO2 (USD/kg). The more carbon productivity increases, the greener growth is achieved. Therefore, this research's hypothesis revealed that financial regulation's influence is positive on carbon productivity, technological innovation is positive, inflation is positive, foreign direct investment is positive, and government expenditure is positive.

RESEARCH METHODS

This research was conducted using a quantitative analysis method from 1996 until 2020. Secondary data for this research was sourced from the OECD Dataset, World Governance Indicator (WGI), Heritage Foundation, World Development Indicator, and World Bank. This study examines a sample comprising the ASEAN-5 Countries, encompassing Indonesia, Singapore, Malaysia, Thailand, and the Philippines. In this study, both dependent and independent variables are utilized as the types of variables. The dependent variable is carbon productivity, which proxies the green growth indicator. The independent variable comprises regulatory quality, economic freedom, technological innovation, inflation, foreign direct investment, and government expenditure. Financial regulation is proxied by regulatory quality and economic freedom, while inflation, foreign direct investment, and government expenditure serve as a control variable. Dynamic Ordinary Least Square is used as the econometric data analysis method.

This study aims to analyze the impact of financial regulations and technology on green growth. The dependent variable, carbon productivity, is a proxy for green growth, while the independent variables include regulatory quality, economic freedom, technological innovation, inflation, foreign direct investment, and government expenditure. This research employs a dynamic Ordinary Least Squares (DOLS) econometric model. The DOLS model is chosen for its ability to analyze the long-term dynamic effects of cointegrated variables. Macroeconomic variables are interrelated and exhibit long-run relationships. DOLS is well-suited for studying these relationships, making it a valuable tool for macroeconomic research. Additionally, DOLS offers practical solutions for endogeneity issues in regressors and serial correlation in error terms (Omri et al., 2019).

The empirical model of this study follows and modifies the empirical model from the research (Cigu et al., 2020). Thus, two empirical models are estimated. The first model is expressed as follows in equation (1).

$$lnCP = \beta_0 + \beta_1 RQ + \beta_2 lnTI + \beta_3 INF + \beta_4 FDI + \beta_5 EXP + \varepsilon t \quad \text{...................... (1)}$$

Then, the second model is expressed in equation (2) as follows.

$$lnCP = \beta_0 + \beta_1 EF + \beta_2 lnTI + \beta_3 INF + \beta_4 FDI + \beta_5 EXP + \varepsilon t \quad \text{...................... (3)}$$

Where ln represents the natural logarithm function, β_0 is the intercept, β_1- β_5 are the elasticity coefficients of each variable, CP is carbon productivity, RQ is regulatory quality, EF is economic freedom, TI is technological innovation, INF is inflation, FDI is foreign direct investment, EXP is government expenditure, and εt is the error term.

DOLS was developed for the first time by Saikkonen (1991) and Stock & Watson (1993) to analyze the panel analog of individual time series regression. The DOLS estimation is expressed below:

$$y_{it} = \phi_i + \delta_t + \beta_i z_{it} + \sum_{j=-p}^{p} d_{ij} \Delta z_{i,t+j} + \mu_{it} \quad \text{... (3)}$$

Where i is the cross-section, t is the time series, ϕ_i is the intercepts indicating individual effects, and δ_t is time trend or effect, Z_{it} is explanatory variables vector, β_i is long-run impact estimation, The first-differenced regressors, leads, and lags are denoted by p, while d_{ij} represents the coefficient for a lead or lag of the first-differenced explanatory variables. μ_{it} is an error term. Furthermore, the DOLS estimated coefficient is calculated by:

$$\hat{\beta}_{DOLS} = \sum_{i=1}^{N} \left(\sum_{t=1}^{T} X_{it} X'_{it}\right)^{-1} \left(\sum_{t=1}^{T} X_{it} \hat{X}_{it}\right) \quad \text{... (4)}$$

where,

$$X_{it} = [z_{it} - \bar{z}_i, \Delta z_i, t-p, \ldots\ldots, \Delta z_i, t+p] \quad \text{.... (5)}$$

The variable X_{it} can be derived from 2(K+1) times one, and $\hat{X}_{it}$ can be obtained from $z_{it} - \bar{z}_i$. Before estimating using the DOLS model, the variables must meet two requirements: the variables should be at least stationer of order difference I(1), and each variable should be cointegrated. The Im Pesharan Shin (IPS) unit root test is used to test the stationarity of each variable. Then, the Westerlund test is used to test cointegration among the variables.

Table 1. Definition of Operational Variables

No	Description	Source
Carbon Productivity **(ln CP)**	This variable is a proxy for Green Growth, calculated as GDP/CO2 (USD/kg).	OECD Dataset
Regulatory Quality **(RQ)**	This variable is proxied by the Regulatory Quality Index, calculated based on perceptions of the government's ability to formulate and implement policies and regulations that both permit and encourage private sector development (Index).	WGI
Economic Freedom **(EF)**	This variable is proxied by the Economic Freedom Index, calculated based on indicators of property rights, judicial effectiveness, government integrity, tax burden, government spending, fiscal health, business freedom, labour freedom, monetary freedom, trade freedom, investment freedom, and financial freedom (Index).	Heritage Foundation
Technological Innovation **(ln TI)**	This variable is proxied by the number of patent applications in each country (Unit).	WDI
Inflation **(INF)**	This variable is proxied by the annual Inflation rate of each country (%)	World Bank
Foreign Direct Investment **(FDI)**	This variable is proxied by the percentage of net foreign direct investment (FDI) inflows to gross domestic product (GDP) calculated by dividing the total value of net FDI inflows by a country's GDP. (%of GDP)	World Bank
Government Expenditure **(EXP)**	This variable is proxied by general government final consumption expenditure (%of GDP)	World Bank

Source: Data Processed, 2024

RESULTS AND DISCUSSION

Before analysing the DOLS estimation, descriptive statistics must be conducted. Based on the descriptive statistics in Table 2, this research conducts 125 observations within 24 years (1996 – 2020). This study transforms several variables into logarithmic forms: the carbon productivity variable (LNCP) and technological innovation (LNTI). Transforming the data into logarithmic form simplifies it and makes analysis more accessible. Other variables, such as INF, FDI, and EXP, are not transformed into logarithms because the variables are formed as percent. Furthermore, index variables, including RQ and EF, are not transformed into logarithm form because the logarithmic transformation of the index form may reduce data values significantly, potentially leading to an abnormal data distribution.

The descriptive statistics in Table 2 showed that LNCP has a mean of 1.6374 with a standard deviation of 0.3554. RQ has a mean of 0.4844 and a standard deviation of 0.8266. EF has a mean of 67.6118 with a standard deviation of 11.2565. LNTI has a mean of 8.6318 with a standard deviation of 0.4742. INF has a mean of 3.8744 and a standard deviation of 5.8664. FDI has a mean of 5.5635 and a standard deviation of 7.3453. For the last, EXP has a mean of 11.2351 with a mean of 2.5295.

Table 2. Descriptive Statistics

Variables	Unit	Mean	Std. Dev.
LNCP	USD/Kg	1.6374	0.3554
RQ	Index	0.4844	0.8266
EF	Index	67.6118	11.2565
LNTI	Unit	8.6318	0.4742
INF	Percent	3.8744	5.8664
FDI	Percent	5.5635	7.3453
EXP	Percent	11.2351	2.5295

Source: Data Processed, 2024

This research also conducted a correlation test to analyze the multicollinearity among variables. The correlation test is presented in Table 3. If the correlation exceeds 0.80, it indicates the presence of multicollinearity between the variables. Table 3 shows that almost all variables correlate 0.80, except for RQ and EF. This means that there is almost no multicollinearity among the variables. The variables can be separated into two distinct models to address the multicollinearity between RQ and EF. Therefore, multicollinearity is not a significant issue in the model.

Table 3. Correlation Test

	LNCP	RQ	EF	LNTI	INF	FDI	EXP
LNCP	1.0000						
RQ	0.4016	1.0000					
EF	0.4311	0.9529	1.0000				
LNTI	0.2119	0.6325	0.6326	1.0000			
INF	0.0373	-0.1288	-0.0814	-0.2012	1.0000		
FDI	-0.5839	0.0426	-0.0274	0.0597	-0.2525	1.0000	
EXP	0.2802	-0.0280	-0.0521	-0.2478	-0.4161	-0.1506	1.0000

Source: Data Processed, 2024

Panel DOLS requires the stationarity of each variable at least on the first difference I (1). Table 4 displays the result of the panel unit root test employing the Im Pesharan Shin (IPS) method. As depicted in the table, two variables are stationers at level I(0), and the remaining are at the first difference I(1). FDI and INF suggest that the probability of each variable ≤ 5% on the level I(0) and first difference order I(1). Meanwhile, LNCP, RQ, EF, LNTI, and EXP have a probability ≤ 5% only on the first difference order I(1). Consequently, it can be inferred that all variables utilized in this study exhibit stationarity on the first difference order I(1), meeting the prerequisite for the model.

Table 4. Result of IPS Unit Root Test

Variables	IPS Result	
	Level I(0)	First Difference I(1)
LNCP	0.7153	-4.0605***
RQ	-0.4271	-4.6690 ***
EF	1.1356	-4.2241***
LNTI	-0.6845	-9.1413***
FDI	-2.6120***	-9.2741***
INF	-2.1535***	-13.0991***
EXP	0.8666	-3.3294***

Note: *** indicates that the variables are significant on α=5%

Source: Data Processed, 2024

The second step in meeting the requirements for the DOLS model involves verifying whether the model is cointegrated. As seen in Table 5, the Westerlund test shows that cointegration exists in both models.

This is evidenced by the p-value ≤ 5% on both models. This outcome confirms that each model variable maintains a long-run relationship, satisfying the prerequisites for utilizing the DOLS model.

Table 5. Result of cointegration test using Westerlund test

Model (1)		
Westerlund test	**Statistics**	***p-value***
Variance Ratio	4.4129	0.0000
Model (2)		
Westerlund test	**Statistics**	***p-value***
Variance Ratio	5.4358	0.0000

Source: Data Processed, 2024

The results of the stationarity and cointegration tests in Tables 4 and 5 indicate that the conditions for running the DOLS model have been met. Thus, the results of the DOLS model are explained in Table 6; the results of Model 1 show that regulatory quality has a significant positive impact on carbon productivity. The coefficient in Model 1 indicates that a 1-point increase in regulatory quality will increase carbon productivity by 0.18% in the long run, ceteris paribus. Model 2 explains that economic freedom has a significant positive impact on carbon productivity. The coefficient in Model 2 indicates that a 1-point increase in economic freedom will increase carbon productivity by 0.014% in the long run, ceteris paribus. Furthermore, Table 6 also showed that adjusted R^2 on both models showed the adjusted R-Square at 62%, which means the dependent explained by 62% variance of independent variables.

Table 6. Estimation Result of DOLS

Dependent Variable: LNCP		
	Model (1)	**Model (2)**
RQ	0.180089**	
	(0.0792622)	
EF		0.0135303**
		(0.0060175)
LNTI	0.1358914	0.1206444
	(0.1784197)	(0.1853406)
FDI	-0.02742***	-0.02502**
	(0.0085963)	(0.0087345)
INF	0.0214768	0.0255645
	(0.0249859)	(0.0254437)
EXP	0.0542071	0.0568768*
	(0.0330205)	(0.0333032)
_const	-0.1690008	-0.9221377
	(1.834931)	(1.686896)
	Adjusted R^2 = 0.6230861	**Adjusted R^2 =** 0.6237561

Note: *, **, and *** indicate that the variables are significant at the α = 1%, 5%, and 10%, respectively.
Source: Data Processed, 2024

This study concludes that financial regulation can promote green growth through carbon productivity. Increased carbon productivity will enhance economic growth while reducing environmental degradation. Furthermore, these findings are consistent with previous studies (Cigu et al., 2020; Odugbesan et al., 2021). Thus, quality regulations and economic freedom can enhance economic growth while reducing environmental degradation. A free economy may solely focus on economic advancement, but this can be controlled by creating well-targeted regulations to support environmental quality (Odugbesan et al., 2021).

The green growth concept emphasizes inclusive opportunities by enhancing innovation and investment related to sustainable development (OECD, 2023). Furthermore, the primary outcomes of green growth encompass related areas such as taxation, innovation, investment, industry, energy, transport, and more. Thus, financial regulation is essential in achieving the green growth concept. As Odugbesan et al. (2021) stated, regulation will control the freedom of the economy to achieve an environmentally friendly economy. However, economic freedom must also be significantly enhanced—the more accessible the economy, the greater the opportunities for investors to invest. Furthermore, there are possibilities for investors to finance environmentally friendly businesses that can enhance economic development. Here, regulation plays an important role in increasing these possibilities. Aron (2000) states that the absence of enforced regulations and laws will lead to direct adverse effects on stakeholders, such as ineffective investment. The negative effect might decrease the environmental quality or the economic growth itself. If environmental quality or economic growth decreases, it contradicts the green growth concept, which aims to enhance both aspects simultaneously. Therefore, the role of regulation is to guide investment and stakeholders toward simultaneously improving environmental quality and economic growth.

The variable of technological innovation in both models indicates that technological innovation does not influence carbon productivity. The coefficients of the technological innovation variable in Models 1 and 2 show a positive impact on carbon productivity. In Model 1, a 1% increase in technological innovation units will drive carbon productivity by 0.14% in the long run, ceteris paribus. Meanwhile, Model 2 indicates that a 1% increase in technological innovation units boosts carbon productivity by 0.12% in the long run, ceteris paribus. Some studies also show results consistent with the research (Samargandi, 2017) and (Du & Li, 2019). Almost all ASEAN-5 countries are developing nations. In these developing countries within the ASEAN-5, the focus is on maximizing economic growth, with less attention paid to environmental quality. Similarly, implementing technology to support ecological quality requires high costs. Hence, Technology development in developing countries is challenging due to these factors (Du & Li, 2019). However, it is still possible to encourage technological development in developing countries. This can be done by raising the standard of living in those countries and gradually improving the environmental quality and economic growth.

The research model uses macroeconomic variables as control variables to manage the estimation results. According to the DOLS estimation results in Table 4, the control variables exhibit diverse outcomes. First, foreign direct investment negatively impacted carbon productivity in both models. The coefficient in model 1 indicates that a 1% increase in foreign direct investment will decrease carbon productivity by 0.2742%. Meanwhile, the coefficient in model 2 indicates that a 1-point increase in foreign direct investment will decrease carbon productivity by 0.02502%. The result aligns with the work of Ozkan et al. (2023) and Rahaman et al. (2022). The deteriorating effect of foreign direct investment on carbon productivity can be explained through the pollution haven hypothesis. The Pollution Haven Hypothesis states that multinational companies tend to invest in developing countries with weak environmental regulations and not environmentally friendly products (Latif et al., 2018). Most of the ASEAN Five countries are included as developing countries with weak environmental regulations. Thus, the increase in foreign direct investment negatively impacts environmental sustainability, making it hard to achieve green growth itself.

Based on the DOLS estimation, inflation shows an insignificant positive influence on carbon productivity in both models. The result contrasts with previous studies showing a significant positive influence on environmental quality (Grolleau & Weber, 2024; Shpak et al., 2022). Grolleau and Weber (2024) state that inflation will slow economic growth and activity. The slowdown of economic activity reduces air pollution. Therefore, it can be concluded that inflation does not significantly contribute to green growth, whereas increasing prices due to inflation reduces economic growth and cannot increase environmental quality.

Government expenditure is the last control variable used in this research, which showed an insignificant positive influence on model 1 and a significant positive influence on model 2. The study is in line with the work of Cigu et al. (2020), which stated a positive influence on carbon productivity in the OECD. The positive impact of government expenditure can be attributed to its allocation towards economic growth initiatives that support environmental sustainability. Therefore, the result of the study implied the significant contribution of government expenditure on green growth.

CONCLUSION

Green growth is crucial in enhancing environmental quality without sacrificing economic growth. This concept can improve ecological quality alongside economic growth in a country. Therefore, financial regulations and technology are indicators of driving green growth. The findings of this study conclude that financial regulations play a vital role in determining the creation of green growth in ASEAN-5 countries. Financial regulations can stimulate the economy through economic freedom, which fosters advanced economic development. Although the economy is free, regulations foster economic growth while maintaining environmental quality. Meanwhile, technological innovation still needs a significant impact on green growth. This is due to the high costs of creating new technologies suitable for mitigating environmental degradation. Therefore, this study recommends the implementation of quality regulations while gradually focusing on developing green growth. Additionally, due to the high costs of green technology innovation, governments can increase investment levels to support innovation in green technology in ASEAN-5 countries. Other than that, governments can also increase their government expenditure, especially in simultaneously supporting economic growth and environmental quality.

REFERENCES

Aron, J. (2000). Growth and Institutions: A Review of the Evidence. In *Source: The World Bank Research Observer* (Vol. 15, Issue 1).

ASEAN. (2022). *ASEAN State of Climate Change Report*.

Cigu, E., Petrişor, M. B., Nuţă, A. C., Nuţă, F. M., & Bostan, I. (2020). The nexus between financial regulation and green sustainable economy. *Sustainability (Switzerland)*, *12*(21), 1–15. https://doi.org/10.3390/su12218778

Climate Watch. (2022). *Historical GHG Emissions*. https://www.climatewatchdata.org/ghg-emissions?end_year=2020&start_year=1990

Degbedji, D. F., Akpa, A. F., Chabossou, A. F., & Osabohien, R. (2024). Institutional quality and green economic growth in West African economic and monetary union. *Innovation and Green Development*, *3*(1), 100108. https://doi.org/10.1016/j.igd.2023.100108

Dong, Z., & Ullah, S. (2023). Towards a Green Economy in China? Examining the Impact of the Internet of Things and Environmental Regulation on Green Growth. *Sustainability (Switzerland)*, *15*(16). https://doi.org/10.3390/su151612528

Du, K., & Li, J. (2019). Towards a green world: How do green technology innovations affect total-factor carbon productivity? *Energy Policy*, *131*, 240–250. https://doi.org/10.1016/j.enpol.2019.04.033

Fan, L. W., You, J., Zhang, W., & Zhou, P. (2021). How does technological progress promote carbon productivity? Evidence from Chinese manufacturing industries. *Journal of Environmental Management*, *277*. https://doi.org/10.1016/j.jenvman.2020.111325

Grolleau, G., & Weber, C. (2024). The effect of inflation on CO2 emissions: An analysis over the period 1970–2020. *Ecological Economics*, *217*. https://doi.org/10.1016/j.ecolecon.2023.108029

Hao, L. N., Umar, M., Khan, Z., & Ali, W. (2021). Green growth and low carbon emission in G7 countries: How critical the network of environmental taxes, renewable energy and human capital is? *Science of the Total Environment*, *752*. https://doi.org/10.1016/j.scitotenv.2020.141853

Hou, S., Yu, K., & Fei, R. (2023). How does environmental regulation affect carbon productivity? The role of green technology progress and pollution transfer. *Journal of Environmental Management*, *345*. https://doi.org/10.1016/j.jenvman.2023.118587

IEA. (2023). *Southeast Asia Energy Outlook 2022*. www.iea.org/t&c/

IEA - International Energy Agency. (2023). *World Energy Outlook 2023*. www.iea.org/terms

IEA- International Energy Agency. (2023). *World Energy Outlook 2023*. www.iea.org/terms

Latif, F., Kuperan, K., & Zaini Abd Karim, M. (2018). *The critical review of the pollution haven hypothesis*. http://hdl.handle.net/11159/1929

Li, S., & Wang, S. (2019). Examining the effects of socioeconomic development on China's carbon productivity: A panel data analysis. *Science of the Total Environment*, *659*, 681–690. https://doi.org/10.1016/j.scitotenv.2018.12.409

Ma, B., Sharif, A., Bashir, M., & Bashir, M. F. (2023). The dynamic influence of energy consumption, fiscal policy and green innovation on environmental degradation in BRICST economies. *Energy Policy*, *183*. https://doi.org/10.1016/j.enpol.2023.113823

Meinshausen, M., Smith, S. J., Calvin, K., Daniel, J. S., Kainuma, M. L. T., Lamarque, J., Matsumoto, K., Montzka, S. A., Raper, S. C. B., Riahi, K., Thomson, A., Velders, G. J. M., & van Vuuren, D. P. P. (2011). The RCP greenhouse gas concentrations and their extensions from 1765 to 2300. *Climatic Change*, *109*(1), 213–241. https://doi.org/10.1007/s10584-011-0156-z

Meng, M., & Niu, D. (2012). Three-dimensional decomposition models for carbon productivity. *Energy*, *46*(1), 179–187. https://doi.org/10.1016/j.energy.2012.08.038

Mohd Suki, N., Mohd Suki, N., Afshan, S., Sharif, A., Ariff Kasim, M., & Rosmaini Mohd Hanafi, S. (2022). How does green technology innovation affect green growth in ASEAN-6 countries? Evidence from advance panel estimations. *Gondwana Research*, *111*, 165–173. https://doi.org/10.1016/j.gr.2022.06.019

Murray, C. J. L., Aravkin, A. Y., Zheng, P., (2020). Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *The Lancet*, *396*(10258), 1223–1249. https://doi.org/10.1016/S0140-6736(20)30752-2

NASA. (2023). *World of Change: Global Temperatures*. https://earthobservatory.nasa.gov/world-of-change/global-temperatures

Odugbesan, J. A., Rjoub, H., Chuka, &, Ifediora, U., Chiemelie, &, & Iloka, B. (2021). *Do financial regulations matters for sustainable green economy: evidence from Turkey*.

https://doi.org/10.1007/s11356-021-14645-4/Published

OECD. (2023). *OECD WORK ON GREEN GROWTH*.

Omri, A., Euchi, J., Hasaballah, A. H., & Al-Tit, A. (2019). Determinants of environmental sustainability: Evidence from Saudi Arabia. *Science of the Total Environment*, *657*, 1592–1601. https://doi.org/10.1016/j.scitotenv.2018.12.111

Ozkan, O., Coban, M. N., Iortile, I. B., & Usman, O. (2023). Reconsidering the environmental Kuznets curve, pollution haven, and pollution halo hypotheses with carbon efficiency in China: A dynamic ARDL simulations approach. *Environmental Science and Pollution Research*, *30*(26), 68163–68176. https://doi.org/10.1007/s11356-023-26671-5

Rahaman, M. A., Hossain, M. A., & Chen, S. (2022). The impact of foreign direct investment, tourism, electricity consumption, and economic development on CO2 emissions in Bangladesh. *Environmental Science and Pollution Research*, *29*(25), 37344–37358. https://doi.org/10.1007/s11356-021-18061-6

Saikkonen, P. (1991). Asymptotically Efficient Estimation of Cointegration Regressions. In *Source: Econometric Theory* (Vol. 7, Issue 1). http://www.jstor.orgURL:http://www.jstor.org/stable/3532106

Samargandi, N. (2017). Sector value addition, technology and CO2 emissions in Saudi Arabia. *Renewable and Sustainable Energy Reviews*, *78*, 868–877. https://doi.org/10.1016/j.rser.2017.04.056

Shpak, N., Ohinok, S., Kulyniak, I., Sroka, W., Fedun, Y., Ginevičius, R., & Cygler, J. (2022). CO2 Emissions and Macroeconomic Indicators: Analysis of the Most Polluted Regions in the World. *Energies*, *15*(8). https://doi.org/10.3390/en15082928

Stock, J. H., & Watson, M. W. (1993). A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems. *Econometrica*, *61*(4), 783. https://doi.org/10.2307/2951763

Tabash, M. I., Farooq, U., El Refae, G. A., & Belarbi, A. (2023). Tackling the ecological footprints of foreign direct investment and energy dependency through governance: empirical evidence from GCC region. *Quality and Quantity*, *57*(5), 4435–4454. https://doi.org/10.1007/s11135-022-01534-2

World Bank. (2012). *The Pathway to Sustainable Development*.

World Bank. (2023). *CO2 Emission (kt)*. https://data.worldbank.org/indicator/EN.ATM.CO2E.KT

Wu, X., Gao, M., Guo, S., & Li, W. (2019). Effects of environmental regulation on air pollution control in China: a spatial Durbin econometric analysis. *Journal of Regulatory Economics*, *55*(3), 307–333. https://doi.org/10.1007/s11149-019-09384-x

Yao, S., Zhang, X., & Wang, Z. T. (2023). On economic agglomeration and carbon productivity in Chinese cities: a spatial econometric analysis. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-023-03034-1

Yilanci, V., Cutcu, I., Cayir, B., & Saglam, M. S. (2023). Pollution haven or pollution halo in the fishing footprint: Evidence from Indonesia. *Marine Pollution Bulletin*, *188*. https://doi.org/10.1016/j.marpolbul.2023.114626