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The relationship between economic diversification and carbon emissions in developing countries

Phan Thi Lieu[1]
Bui Hoang Ngoc[2*]

[1]*Faculty of Human Resources Management, University of Labour and Social Affairs, Ho Chi Minh City campus, Vietnam.*
Email: lieupt@ldxh.edu.vn
[2]*FEMRG Research Group, Ho Chi Minh City Open University, Ho Chi Minh City, Vietnam.*
Email: ngoc.bh@ou.edu.vn

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(Corresponding Author)*

Abstract

In the past two decades, ASEAN countries have witnessed a rapid rise in air pollution, and environmental degradation has become a severe problem in this region. This is because manufacturing, machinery, chemicals, and allied industries are the main economic sectors on which developing nations in the ASEAN-5 area have concentrated their efforts. However, these are significant sources of greenhouse gas emissions. In response, each of the ASEAN-5 nations has pledged to reduce its carbon emissions. Additionally, one of the crucial challenges that these nations face is the choice and modification of product structure. This study was conducted to analyze the impact of economic diversification, income per capita, foreign direct investment, and electricity consumption on carbon emissions in developing ASEAN-5 nations (Vietnam, Thailand, Indonesia, Malaysia, and the Philippines) from 1986 to 2019. By adopting the pooled mean group approach, the empirical results showed that economic diversification reduces CO_2 emissions while its square has the opposite effect. Electricity consumption positively influences carbon emissions in the long run, while economic growth drives environmental degradation both in the short and long run. Based on the findings, it can be recommended that ASEAN-5 governments increase economic diversification and reduce non-renewable energy consumption to promote sustainable development and environmental protection.

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1. Introduction

When an economy is heavily reliant on agricultural and mining income, it is difficult to sustain long-term economic growth. These industries' commodities are erratic, their allocative efficiency is low, and their productivity develops more slowly than that of other industries. Even if a nation decides to pursue a development path that relies on natural resources, macroeconomic stability is at risk, the manufacturing sector is often overburdened, and the likelihood of civil disturbance increases (Esanov, 2012). Governments, therefore, have started to focus on the development and application of economic diversification plans in an effort to remedy this issue. Economic variety is now regarded as essential for sustained economic progress. Economic diversification is particularly necessary in developing countries, least developed countries, landlocked developing countries, and small islands because it promotes structural transformation and economic development while also creating jobs (Freire, 2017).

Recognizing that economic diversification improves a country's economic performance, much of the discussion about economic policy and long-term growth revolves around the design and implementation of strategies to increase economic diversification. Studies have aimed to comprehend the performance, interconnection, and complexity of the execution of economic diversification policies – specifically, by developing and testing reliable empirical methods for measuring economic diversification, the determinants of economic diversity promotion, and the impact of diverse policies on sustainable development. In order to design and implement policies to counteract climate change and promote sustainable economic development, economic diversity has been incorporated into many nations' development plans (Abubakar & Abdullahi, 2022; Ferraz, Falguera, Mariano, & Hartmann, 2021; Yuang & Zhang, 2022).

Although the Association of Southeast Asian Nations (ASEAN) has emerged as one of the world's most economically dynamic regions, it still faces several challenges. The majority of the ASEAN economies are still small and unable to compete with global economic centers. The economics of these nations, in particular, are still relatively simple; specifically, the economic complexity index of the five developing ASEAN countries only reached 0.014 in the period 1986–2019. This presents challenges both for competitiveness and the achievement of sustainable growth. Besides economic problems, ASEAN countries also face certain environmental challenges. The main contributors to environmental issues are urbanization and population increase, the overuse of natural resources, and climate change. In addition to these significant difficulties, ASEAN countries' environmental issues are also impacted by the fact that some nations create unsuitable development plans, drawing large amounts of investment but offering limited options. Additionally, environmental protection laws and policies have neither been coordinated nor strictly implemented. These challenges have had a significant impact on the region's ecological environment, making it difficult to maintain ASEAN countries' sustainable development.

Since most countries and regions set sustainable development goals, clarifying the relationship between economic diversification and environmental quality makes both theoretical and practical sense. However, this topic is still considered new, and little research has been conducted. Furthermore, the disparity in the conclusions of existing studies makes it impossible to confirm the positive role of economic diversification in environmental improvement. In light of these factors, this study examined the connection between economic diversification and CO_2 emissions. The authors investigated the connection between economic diversification and CO_2 emissions in 5 emerging ASEAN nations using the pooled mean group (PMG) approach. The findings of the research serve as the foundation for appropriate conclusions to be drawn and recommendations to be made for reducing emissions in these developing countries. This study's contributions are reflected in the following key points:

(1) According to the authors' knowledge, little analytical research on the connection between economic diversification and CO_2 emissions in ASEAN nations has been conducted. In a related study, Nathaniel (2021) investigated the association between the economic complexity index and ecological footprint (indicating environmental quality) in ASEAN nations (the Philippines, Indonesia, Singapore, Malaysia, Thailand, and Vietnam).

(2) The study of the effect of the economic complexity index and its square on the change in CO_2 emissions in the research area is another unique feature of this study when compared to other studies on the same issue. The squared economic complexity index (ECI) variable was added to assist in the study's testing of the hypothesis that improving economic diversification will affect emissions.

2. Background Theory and Literature Review

2.1. Concepts

Economic diversification is the transition to a more diverse structure of domestic production and trade in order to increase productivity, create jobs, and lay the groundwork for long-term poverty reduction. A measure of variety is beneficial since it offers a way to monitor the success and development of a nation's economy (Xu, Cheng, Chen, & Templet, 2002). Similar to Xu et al. (2002), Wadi and Ala'G (2018) defined economic diversification as a change in economic structure characterized by a diversification of revenue sources. It helps countries conduct economic activities to achieve sustainable growth and development. Diversification and expansion create the stability, security, and reliability that developing countries need, rather than relying on often volatile primary commodity production (Wadi & Ala'G, 2018).

Alternatively, Anyaehie and Areji (2015) asserted that economic diversification was the process of expanding the range of economic activity in terms of both production and distribution of commodities and services. While it may not always result in higher productivity, diversifying an economy's economic foundations improves economic stability. The issue of economic diversification should be viewed from the perspective of sustainable development to ensure the long-term stability of the economy. Specifically, the ability of the economy to adjust to the loss of natural resources is substantially strengthened by economic diversification. Additionally, it aids in coping with the atypical economic changes brought on by the fierce competition of globalization.

In general, indicators of economic diversification can be divided into two main groups: (1) a group that measures the absolute level of specialization of a country (e.g., ogive index, entropy index, Herfindahl-Hirschmann, Gini index, complexity index), and (2) a group that measures a country's economic structure based on a group of reference industries (e.g., Theil Index, relative Gini index, inequality in manufacturing sectors). In this article, economic diversification is regarded in terms of the diversity in the structure of a country's exports. The measurement of the share of industries in exports is considered a reliable proxy for measuring economic diversification. Therefore, this study used the economic complexity index as a proxy for economic diversification.

2.2. Background Theory

2.2.1. Environmental Kuznets Curve (EKC)

In the 1970s, the debate on the relationship between growth and the environment centered on the "Limits to Growth" report by the Club of Rome. Economists argued that substitution and innovation could help reduce environmental impacts, although this was a minority opinion. The mainstream view was that the environment and the economy were two conflicting goals. Moreover, in the late 1980s, the notion of "too poor to be green" emerged. This viewpoint contends that developing nations lack the resources necessary for both environmental preservation and economic development. As a result, these nations must grow in order to gain the necessary resources to achieve their environmental goals. Economic experts and econometricians have been interested in estimating empirical correlations between GDP and environmental quality measures since the early 1990s, and they embodied this concept in empirical models as environmental Kuznets curves (EKCs). EKC is named after the economist Kuznets, who proposed that the relationship between the measure of inequality in income distribution and income levels takes the shape of an inverted U-curve. Pollution or other degradation increases in the early stages of economic development and decreases in the later stages.

2.2.2. STIRPAT Model

The stochastic impacts by regression on population, affluence, and technology (STIRPAT) model was proposed by Dietz and Rosa (1997). It was based on the Impact-Population-Affluence-Technology (IPAT) model of analyzing the impact of human activities on the environment (Council, 1992; Harrison & Pearce, 2000), where I is the impact on the environment, generated by population (P), affluence expressed through per capita income (A), and technology (T). The STIRPAT equation resembles the IPAT equation, but with more variables. The model has been restructured as follows:

$$I_i = aP_i^b A_i^c T_i^d e_i$$

Where a is a constant; b, c, and d are exponents; subscripts (i) for I, P, A, and T show that these quantities vary with observed units; and error (e) is a residual representing the variation between observation units (York, Rosa, & Dietz, 2003). STIRPAT is an interdisciplinary model that connects the natural sciences (an ecological computational equation) with the social sciences (social science theories and methods) (Dietz & Rosa, 1994). STIRPAT can be extended to include any other relevant variables, such as political, social, cultural, and others.

2.3. Literature

The role of economic diversification and variety in lowering CO_2 emissions has been the subject of some research. Some authors have used the economic complexity index as a proxy for diversification. However, other authors argue that economic complexity has broader connotations than diversification (Ferraz et al., 2021).

Can and Gozgor (2017) investigated the impact of economic diversification on carbon emissions in France between 1964 and 2014. They also took the impact of energy consumption on CO_2 emissions into account. First, they noted that France provides a viable testing ground for the EKC theory. Second, they found that energy usage had a favorable impact on CO_2 emissions. Third, they discovered that increased economic complexity over the long term lowered CO_2 emissions. The results had important environmental policy implications for reducing France's CO_2 emissions and showed the positive role of economic diversification in reducing carbon emissions in this country. The studies of Romero and Gramkow (2021), Zheng, Zhou, Rahat, and Rubbaniy (2021), and Li, Geng, Shinwari, Yangjie, and Rjoub (2021) came to similar conclusions. In addition to the favorable remarks, some studies also demonstrated that economic diversification was the cause of a rise in carbon emissions into the environment (Boleti, Garas, Kyriakou, & Lapatinas, 2021; Neagu, 2019). Boleti et al. (2021) examined the relationship between economic complexity and environmental performance in 88 developed and emerging countries from 2002 to 2012. The study's findings showed that economic complexity had a negative impact on air quality, increasing exposure to PM2.5, CO_2, methane, and nitrous oxide emissions. According to You, Zhang, and Lee (2022), depending on the state of the economy, the impact of economic diversification on CO_2 emissions can be either good or detrimental.

An inverted U-shaped relationship between economic diversification and carbon emissions was also found in the studies of Balsalobre-Lorente, Ibáñez-Luzón, Usman, and Shahbaz (2022) and Neagu (2019). Neagu (2019) applied the EKC model to explore the link between the economic complexity index (ECI) and carbon emissions. The study was carried out for 25 countries in the European Union (EU) from 1995 to 2017. The research results showed that depending on the complexity of the economy, the CO_2 emission pattern exhibited an inverted U-shaped curve. Pollution increased in the early stages as countries increased the complexity of the products they exported; however, after a tipping point, an increase in economic complexity suppressed pollutant emissions.

Laverde-Rojas, Guevara-Fletcher, and Camacho-Murillo (2021) investigated the relationships among economic growth, economic complexity, and CO_2 emissions in Colombia from 1971 to 2014. They used a vector error correction model to verify whether there was a long-term relationship between the variables. Additionally, they used dynamic least squares, fully modified least squares, and canonical cointegration regression to verify the robustness of the results. The findings demonstrated that the EKC was absent for a developing nation like Colombia that had not yet benefited from rises in economic complexity. Before reaping the environmental advantages of more sophisticated products, nations arguably face several challenges. Some may be caused by a nation's institutional and production rigidities, which allow for the intervention of public policy. Ngarava (2021) investigated the relationship between economic diversification and CO_2 emissions in southern African countries. Similar to Laverde-Rojas et al. (2021), there was no long-run relationship between economic diversification and CO_2 emissions.

Previous research has shown that the study of the relationship between economic diversification and CO_2 emissions is still limited in terms of the number of works and research methods and hampered by diversity in conclusions. In addition, no studies have yet explored the effects of simultaneous economic diversification and squared economic diversification on CO_2 emissions. The connection between these two variables in developing nations is, therefore, a novel and fascinating subject.

3. Research Model, Data Sources, and Methodology

The study focused on determining the impact of economic diversification on the CO_2 emissions of Asian developing countries. Based on the theories and studies outlined above, the initial model was proposed as:

$$CO_{2it} = \beta_0 + \beta_1 ECI_{it} + \beta_2 ECI_{it}^2 + \beta_3 GDP_{it} + \beta_4 FDI_{it} + \beta_5 lnEC_{it} + u_{it} \quad (1)$$

Where: u is the error term, t is the year (from 1986 to 2019), and i is the country. Table 1 provides a detailed description of the variables in the model.

Table 1. The study variables and data sources.

Variable	Variable explanation	Unit	Data sources
CO_2	Annual CO_2 emissions per capita	Tons	Our world in data - OWID
ECI	Economic complexity index	Score	Observatory of economic complexity - OCE
GDP	Per capita income at fixed prices in 2010	USD	World bank
FDI	Foreign direct investment inflows per capita	USD	United nations conference on trade and development - UNCTAD
EC	Electricity consumption per capita	kW h	World bank

Traditional estimation methods for panel data, such as fixed effects (FE) or random effects (RE) models, are effective when there is sufficient data for T time periods and N units. This study, however, employed a sample with T = 34 and N = 5, which is not ideal for estimating coefficients using RE or FE models due to the limited amount of data. For panel data, however, conventional estimate approaches include not only the dependent and independent variables' long- and short-term relationships. Consequently, the research employed a method of dealing with short- and long-run heterogeneity of panel data, the pooled mean group (PMG) of Pesaran (1997), Pesaran, Shin, and Smith (2001), and Pesaran and Smith (1995), which has numerous benefits. This estimator allows the cointegration form of the underlying ARDL model to be used and adapted to panel data. Accordingly, the PMG method was used to estimate the error correction of the set of variables related to the model:

$$\Delta Y_{it} = \sum_{j=1}^{p-1} \gamma_j^i \Delta Y_{i,t-j} + \sum_{j=0}^{q-1} \delta_j^i \Delta X_{i,t-j} + \varphi^i [Y_{i,t-1} - \{\beta_0^i + \beta_1^i X_{i,t-1}\}] + \varepsilon_{it}$$

Where ΔY_{it} is the dependent variable of the model Y_{it}.

$Y_{i,t-j}$ is the lagged variable of order j of the dependent variable.

X is the set of independent variables.

$\varepsilon_{it} = \lambda_i + \lambda_t + \nu_{it}$ is the error of the model, including the object-specific component λ_i, constant over time λ_t, and random error ν_{it}.

γ_j^i, δ_j^i is the short-run component of the estimated coefficients.

β_0^i, β_1^i is the long-run component of the estimated coefficients.

φ^i is the long-run equilibrium adjustment component.

Table 2. Descriptive statistics.

Variables	Mean	Std. dev.	Min	Max
CO_2	2.4572	2.1570	0.2614	8.7218
ECI	0.0140	0.5417	-1.1901	1.0885
ECI^2	0.2919	0.3473	4.24E-08	1.4163
FDI	80.696	96.800	-21.4237	425.7348
GDP	3374.275	2411.326	481.290	11414.58
lnEC	4.1652	0.8702	1.7096	5.6310

4. Empirical Results

4.1. Descriptive Statistics

Table 2 demonstrates that in 33 years, per capita CO_2 emissions in Southeast Asian emerging nations grew more than 33-fold. Per capita CO_2 emissions in the period 1986–2019 reached a minimum of 0.26 tons per person and a maximum of 8.72 tons per person. Meanwhile, the economic complexity of the countries in the study area improved quite slowly. The highest economic complexity index was approximately 1.1. In addition, the period 1986–2019 also witnessed the transition of countries in the study area from low-income to middle-income countries by improving the gross domestic product (GDP) per capita. Similarly, the level of foreign direct investment in these countries changed, reaching an average of 80 USD per person for the whole period. The descriptive statistics of the variables in the model are illustrated in more detail in Table 2.

4.2. Empirical Results

4.2.1. Unit Root Test

PMG cointegration vector model estimation requires that the variables included in the model have cointegration properties. Therefore, it was necessary to test the stationarity of the data series as well as the cointegration of the dependent and independent variables in the model. The model used the Fisher unit root test based on an augmented Dickey-Fuller platform. The results revealed that the stationary variables were mixed at 0 and 1, I(0) and I(1), as shown in Table 3.

Table 3. Results of the unit root test.

Variable	Level	First difference
	ADF - Fisher chi-square	ADF - Fisher chi-square
CO_2	4.60341	54.2071***
ECI	11.0260	46.8993***
ECI^2	38.3696***	58.8933***
FDI	11.8574	88.7429***
GDP	0.20179	26.7642***
lnEC	32.5061***	27.5036***

Note: *** $p<0.01$.

4.2.2. Cointegration Test

A Westerlund test was conducted with an H_0 hypothesis (no cointegration) and an H_1 two-choice hypothesis (some chains have a cointegration relationship and all chains have a cointegration relationship). The test results showed that the chains included in the PMG model estimate had a cointegration relationship, which increased the reliability of the estimated values from the model, as shown in Table 4.

Table 4. Cointegration test result.

Hypothesis	t	P-value	Conclusion
H_0: No cointegration	-1.7876	0.0369	Rejected
H_1: Cointegration			Accepted

Table 5. The short-term results.

Variable	Coefficient	Std. error	t-statistic
CointEq(-1)	-0.5892	0.3679	-1.6014
Δ(CO2(-1))	0.4179	0.4222	0.9900
Δ (CO2(-2))	0.1731	0.2368	0.7308
Δ (ECI)	0.7567	0.7609	0.9945
Δ (ECI(-1))	-0.0056	0.1704	-0.0331
Δ (ECI(-2))	-0.4271	0.4065	-1.0505
Δ (ECI^2)	-0.8638	0.6127	-1.4099
Δ (ECI^2(-1))	0.3099*	0.1811	1.7112
Δ (ECI^2(-2))	0.7009	0.4570	1.5337
Δ (lnEC)	-0.5005	2.5614	-0.1954
Δ (lnEC(-1))	-1.4483	1.3313	-1.0878
Δ (lnEC(-2))	-1.0185	0.6333	-1.6081
Δ (GDP)	0.0010*	0.0005	1.9226
Δ (GDP(-1))	0.0005	0.0003	1.5089
Δ (GDP(-2))	-0.0004	0.0005	-0.7792

Variable	Coefficient	Std. error	t-statistic
Δ (FDI)	0.0001	0.0010	0.0352
Δ (FDI(-1))	0.0003	0.0011	0.2932
Δ (FDI(-2))	0.0004	0.0009	0.5130
C (Intercept)	-0.4382	0.5217	-0.8399

Note: * p<0.1

4.2.3. Short-Run Impact Analysis

The results of the short-term analysis showed that the first-order lagged variable of the square of economic diversity had a significant impact at the 1% level on CO_2 emissions in developing Asian countries. This effect was in the same direction, meaning that the more these countries diversify their economies, the more emissions increase. Additionally, the short-term analysis demonstrated that economic growth (via per capita income) was a factor in the rise in CO_2 emissions in the research region. Table 5 shows that the coefficient of CointEq(-1) was negative, implying that carbon emissions can re-adjust to the long-term equilibrium point.

4.2.4. Long-Run Impact Analysis

The findings of the long-term investigation showed that economic diversification has a detrimental effect on CO_2 emissions. However, variety has a similar effect on emissions when it increases to a certain point. Specifically, if ECI increases by 1 point, CO_2 emissions decrease by 0.45 tons per person. But if the value of ECI^2 increases by 1 point, the CO_2 emissions increase by 0.2 tons. The findings of the long-term analysis also indicate that electricity use is one of the major contributors to CO_2 emissions in these ASEAN developing nations.

Table 6. The long-term results.

Variable	Coefficient	Std. error	T-statistic
ECI	-0.4568***	0.0738	-6.1854
ECI^2	0.2034**	0.1121	1.8146
lnEC	0.5051***	0.0573	8.8072
GDP	0.0002***	0.0004	5.0859
FDI	-0.0001	0.0003	-0.5591

Note: ** p<0.05, *** p<0.01.

4.3. Discussion

The findings demonstrate that economic diversification affects CO_2 emissions over the long term, and the effect is U-shaped. Initially, when economic diversification increases, CO_2 emissions decrease. When the level of economic diversification has reached a certain point, it will start to increase emissions. These results are not entirely consistent with previous studies. The effect of economic diversification on carbon emissions is similar to that found by Can and Gozgor (2017), Romero and Gramkow (2021), Zheng et al. (2021), and Li et al. (2021). Conversely, if economic diversification increases to a certain extent (economic complexity squared), its impact on CO_2 emissions is in the same direction, which is similar to the findings of Boleti et al. (2021) and Neagu (2019). Furthermore, the use of electricity for social and economic functions in these developing Asian nations affects the growth of carbon emissions, which is consistent with previous research findings. The authors believe that the following factors may explain this result:

All the analyzed countries were developing countries. The economies of these countries have long depended on agriculture and natural resources. Therefore, when countries change their production structure, increasing economic diversification by increasing the complexity of the economy will have benefits for the environment. However, once economic diversification reaches a certain point, attention must also be paid to the problems of energy usage and technology. If these issues are not addressed, increasing economic diversification by producing more products with a higher degree of complexity could threaten the environment in these countries. This information is critical for policymakers as ASEAN countries are not only interested in diversifying their domestic products and increasing their "know-how" but also in technological advances.

Moreover, the use of electric energy in Asian countries is also a significant source of CO_2 emissions. Energy is vital to meet the demand for a significant economic shift. According to the International Energy Agency (IEA), to overcome the electricity deficit, ASEAN countries must add 354,000 megawatts (MW) of generating capacity by 2040. The increase in CO_2 emissions is understandable, given that the majority of electricity in the region is generated using non-renewable fuels such as oil and coal. For instance, the yearly consumption of energy in Vietnam went from 8.6 TWh in 1990 to 240.1 TWh in 2019. During this time, the yearly rate of increase decreased by roughly 12–15%, or twice as fast as the GDP. Coal, natural gas, and hydroelectricity are the three main energy sources used to produce power; specifically, the largest percentage was coal (41.6%), followed by hydropower (37.3%) and gas (18.8%). Non-renewable resources are more affordable and readily available in emerging nations. In actuality, ASEAN nations have the capacity to utilize more renewable energy, including hydropower, geothermal, biomass, wind, and solar energy. However, their use has not kept up with their potential due to a lack of resources and technology.

5. Conclusion and Policy Implications

The purpose of this study was to investigate how economic diversification (measured by the economic complexity index) affects CO_2 emissions in Southeast Asian developing nations. By using the PMG estimation method for panel data for the period 1986–2019, certain conclusions could be drawn:

(i) Economic diversification has a positive impact on long-term carbon emission reduction in the study countries.

(ii) Squared economic diversification has a positive impact on carbon emissions in both the short and long term in these countries.

(iii) The consumption of electrical energy is another cause of increased carbon emissions.

Based on the findings, the authors make the following recommendations to help reduce CO_2 emissions in Southeast Asian developing countries:

First, it is necessary to improve economic diversification by increasing the economic complexity index. This will help countries in the study area to improve the environment and lower CO_2 emissions. In turn, economic complexity is correlated with knowledge expansion, and policy initiatives are influenced by research on information transmission (Hidalgo, 2021). Thus, ASEAN developing countries must improve the quality of their human resources. Furthermore, policies to create mechanisms to increase economic diversification also need to be implemented – for example, promoting digital transformation, focusing on and investing in technology for complex products with high scientific content, and more.

Second, along with increasing economic complexity, the application and improvement of technology should also be given due attention, especially the development of environmentally friendly technologies. To accomplish this, appropriate and effective research and development investment is required. In addition, countries in this region should be cautious and selective in attracting foreign investment sources. Governments should prioritize attracting green, modern technologies and boldly rejecting environmentally intensive technologies, even if they would help these countries make faster technological advances.

Third, it is necessary to maintain and promote ASEAN's grid connection project. This is a flagship program of the ASEAN Vision 2020 and aims to connect countries with excess power generation capacity with those that face power deficits. The goal of a regional grid is to reduce the cost of building energy infrastructure while assisting all members in meeting the region's expanding energy needs.

Fourth, the increased use of renewable energy sources must be the primary goal of the green growth strategy, in tandem with ASEAN's multi-sector economy and environmental priorities. Regional trade liberalization will make it easier to transmit technological innovation, and regional obstacles must be eliminated in order to encourage efficient renewable energy use.

Fifth, the countries under consideration should take note of and implement the lessons learned from Singapore's carbon tax. In order to lower CO_2 emissions, a carbon tax can be a useful strategy, concurrently promoting green growth while helping to raise state revenues for reinvestment in environmental preservation.

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