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SMEs and carbon neutrality in ASEAN: the need to revisit sustainability policies

Naoyuki Yoshino[a], Ehsan Rasoulinezhad[b], Han Phoumin[c] and Farhad Taghizadeh-Hesary[d]

[a]School of Economics, Keio University, Tokyo, Japan; [b]Faculty of World Studies, University of Tehran, Tehran, Iran; [c]Economic Research Institute for ASEAN and East Asia, Jakarta, Indonesia; [d]School of Global Studies, Tokai University, Hiratsuka, Japan

ABSTRACT

Most rules and regulations for protecting the environment and reducing greenhouse gas emissions target large enterprises. Although small and medium-sized enterprises (SMEs) have major shares in most Asian economies, they remain outside the purview of most environmental rules and regulations. The primary purpose of this study is to assess the association between SMEs' activities and carbon emissions in the Association of Southeast Asian Nations (ASEAN) countries from 2010 to 2020. To this end, a fully modified ordinary least squares (FMOLS) model was developed. The results show that SMEs' activities do not align with environmental protection goals and sustainable development, as the estimation results revealed their significant contributions to CO2 emissions. Other practical implications of this study for carbon-neutral SMEs are introducing green finance policies, revisiting the environmental and carbon reduction rules and regulations that cover SMEs, and changing banks' lending mechanisms based on SMEs' green economic performance.

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1. Introduction

Small and medium-sized enterprises (SMEs) and their essential role in the economic activities of different countries, especially developing ones, have been recognised by experts (e.g. see Manzoor et al., 2021) and economic policymakers. How an SME plays a major role in an economy can be interpreted from different perspectives. First, it is labour-oriented and will have a special place in hiring skilled or capable labour. In developing countries, where the concept of elite migration (brain drain) has become a major challenge, the development of SMEs can lead to job creation for the elite, reducing the rate of brain drain in these countries. Second, these firms' organisational agility and economic opportunities are higher than those in large firms

CONTACT Farhad Taghizadeh-Hesary farhad@tsc.u-tokai.ac.jp

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(broad organisational chart, slow operation). Another influential aspect of SMEs is that their development in an economy will lead to the improvement of the market-oriented system, expansion of the private sector, globalisation, trade liberalisation, and improvement of the business and investment environment.

There are many positive aspects of the development of SMEs that have been mentioned, but despite the various programs to support its development (e.g. ASEAN Strategic Action Plan for SME Development 2016–2025; The Green Action Plan (GAP) for SMEs in the EU), the outbreak of COVID-19 in late 2019 negatively impacted the activities of these enterprises. Dai et al. (2021) and Ozanne et al. (2022) noted that the implementation of lockdown due to COVID-19 in China resulted in the temporary closure of over 80% of SMEs in early 2020. Owing to their small and medium capital, these firms did not have high financial resilience to the pandemic shock, and many were forced to cease operations temporarily or permanently.

Notably, the outbreak of COVID-19, despite its profound negative effects on the functioning of global economic systems, has reduced environmental pollution and led to the hope of achieving sustainable development in the near future. Sustainable development refers to achieving the desired conditions for human life on the planet, one of which is the existence of a clean environment. Sikarwar et al. (2021) noted that reduced urban transport, urban traffic, and air travel were the most important contributing factors to the reduction of environmental pollution during COVID-19. Alava and Singh (2022) noted that the temporary closure of many manufacturing plants and their reduction in energy and electricity consumption due to COVID-19's evolution into a pandemic contributed to the reduction in global greenhouse gas emissions. However, a group of scholars (e.g. Li & Li, 2021) noted that while COVID-19 resulted in a temporary reduction in environmental pollution, there will be a rebound in carbon emissions globally in the post-COVID era.

We examine the role of SMEs in achieving sustainable development, particularly carbon neutralisation (achieving a green economy or zero carbon). One view opines that these enterprises do not significantly contribute to carbon dioxide (CO2) emissions and environmental pollution, but contrary to popular belief, they do in many parts of the world. For instance, according to the SAP News Center (2021, April 15), SMEs contribute to over 70% of industrial pollution in Europe, which is considerable. In China, SMEs' contribution to CO2 emissions was over 65% in 2010 (Meng et al., 2018). Interestingly, SMEs emitted over 29 million tons of CO2 in Southeast Asia in 2021 (Eco-Business, 2022, January 12). Therefore, it should be noted that despite the advantages of SME development, the pattern of sustainable development in these enterprises is not observed. In the post-COVID era, policymakers should pay more attention to economic recovery through SME development.

Studying the relationship between SMEs and environmental pollution is vital for ASEAN (the Association of Southeast Asian Nations) countries. This importance can be interpreted in two ways: First, ASEAN member countries have prioritised sustainable national energy and clean energy in their national and collective programs in recent decades. It is also worth noting that despite the adverse effects of COVID-19 on the economies of ASEAN countries, the approach to green economic recovery in the post-COVID-19 era in these countries is of interest to officials and government

institutions. In a recent study, Lau (2022) mentioned that ASEAN countries exhibit a high tendency to boost green technologies and renewable energy consumption in the near future. Husaini and Lean (2022) declared that COVID-19 had created various opportunities for ASEAN countries to achieve energy sustainability and digitalisation.

Meanwhile, ASEAN members have developed conditions for SMEs' growth to reach a higher employment rate, productivity, and GDP growth. Regarding the ASEAN SME Policy Index 2018, from the beginning of 2000, the development planning of SMEs was specially designed, and appropriate structures and regulations were formed for establishing and expanding these enterprises over time. However, as previous scientific research shows, the development of SMEs is not in line with environmental protection, and the participation of these enterprises in the emission of greenhouse gases in ASEAN countries is significant.

The major contributions of this paper to the literature are as follows. First, many studies have focused on the role of large industries such as power plants in environmental pollution, but statistics from different countries show that SMEs have also made significant contributions to greenhouse gas emissions. This study focuses on theoretical and experimental studies on the effects of SMEs on CO2 emissions. Second, the relationship between SMEs and CO2 emissions based on a theoretical mathematical model is discussed and interpreted. Third, in econometric modelling, an attempt has been made to combine the effects of variables such as industry growth, globalisation, and the green economy index. Thus, conclusions can be drawn along with the acceptance/rejection of industrialisation, globalisation, and green economic revival policies for ASEAN countries.

The rest of the paper is structured as follows. Section 2 discusses the current literature. Section 3 represents the theoretical background. Next Section 4 introduces the variables and the experimental model. Section 5 presents the main findings. Finally, Section 6 presents the key points of the research and discusses the proposed practical policies.

2. Literature review

The literature has addressed the issue of enhancing the environmentally friendly activities of SMEs. Zeng et al. (2011) highlighted the factors influencing the environmental performance of SMEs, focusing on China. They concluded that social and market factors as well as the government's financial support for these enterprises are the three major drivers of SMEs environmentally friendly activities. Hoogendoorn et al. (2015) attempted to determine the driving force of green SMEs' activities. Their findings reveal that efficient legislation, annual monitoring, and green facilities provided by the government can motivate SMEs to accept green economic performance. In another study, Efobi et al. (2019) examined the environmental protection plans of over 840 SMEs in Nigeria and Ghana. Their findings revealed the low efficiency of environmental policies by these SMEs owing to major reasons such as outdated production technologies, high energy intensity, and the lack of concern of managers of SMEs on the issue of environmental protection.

Lopes de Sousa Jabbour et al. (2020) argued that manufacturing SMEs contribute more to air pollution, and to solve the problem, countries should improve knowledge-based economic policies and lean manufacturing systems. Johnstone (2021) examined a group of SMEs in Northern Europe and concluded that these enterprises need to have a defined environmental management process to make activities in line with sustainable development. Yin et al. (2022) argued for green entrepreneurship for SMEs in China. They expressed that in the post-COVID era, it is necessary to raise SMEs with specifications for green innovation and green business models. This is in line with Yan et al. (2022), who proposed the improvement of eco-innovation (EI) in SMEs. This would place the activities of SMEs on the road to sustainable economic growth in the post-COVID era. However, due to these firms' small and medium capital, it is somewhat unreasonable to expect their activities to progress in line with the issue of a green economy in the COVID-19 and post-COVID-19 eras. Haiyang and Xiaohui (2022) addressed the issue of finding ways to financially support SMEs by bringing about a green transformation in the structure of their operations and production. Alam et al. (2022) focused on 14 developing economies and tried to explore the efficiency of SMEs in environmental protection. Their major findings confirmed the positive role of high-profit firms in lowering the threat of climate change. Le (2022) expressed that through corporate social responsibility, SMEs are important to promoting green innovation in the post-COVID-19 era.

Other studies focused on the direct and indirect impacts of SMEs' activities on environmental pollution. Rawlings et al. (2014) mentioned that it is a fact that SMEs consume a large volume of energy; however, most of them are low-carbon emitters. In a recent study, Samargandi and Sohag (2022) and Al-Hakimi et al. (2022) expressed that SMEs can help a country like Saudi Arabia promote green energy consumption due to their SMEs' potential to promote green energy and their agility to accept energy transformation. Xiang et al. (2022) declared that many SMEs in China have become more environmentally efficient through the Twelfth Five-Year Plan for National Environmental Protection. Zhang and Fang (2022) examined a group of SMEs in the EU and concluded that eco-friendly SMEs have come up during the COVID-19 pandemic due to the supportive plan of European Union (EU) governments targeted at green SMEs.

In contrast, Gombault and Versteege (1999) proved that SMEs largely contribute to industrial environmental pollution. They highlighted the good experience of SMEs in the Netherlands, where the government employed different supportive packages and legislation for cleaner activities of SMEs. Meng et al. (2018) investigate the role of SMEs in the environmental pollution in China. They found that SMEs in the power and heat sectors are the most significant contributors to CO_2 emissions in China. Fawcett and Hampton (2020) studied SMEs' environmental activities in the UK and the EU. They concluded that SMEs play an essential role in emitting CO_2, and governments should implement urgent policies to increase the energy efficiency level of SMEs' activities. Lopes de Sousa Jabbour et al. (2020) analysed a group of Asian SMEs. They proved that despite the high potential of SMEs for inclusive economic growth and sustainable development, their contributions to waste generation and air and water pollution are considerable. In a recent study, Dadhich and Hiran (2022) investigated the role of SMEs in improving corporate environmental sustainability through a survey method. The results confirmed that SMEs could make greening activities leading to a higher rate of corporate

environmental sustainability. Choudhary et al. (2022) analysed the impacts of 305 SMEs. They found that in the post-COVID-19 era, they are not eager to develop eco-friendly performance, which would threaten the goal of global sustainable development. Shihata et al. (2022) argued that the advantages and financial incentives provided by governments for accomplishing sustainable development goals should be defined for micro, small, and medium enterprises because of their significant contribution to environmental pollution. In another recent study, Chatzistamoulou and Tyllianakis (2022) evaluated the role of SMEs in European green growth. They found out that the positive role of SMEs in green growth needs supportive regulation and financial resources by governments.

A literature review indicates that SMEs' effect on CO_2 emissions is unclear. Depending on government policies and the SMEs' structure of activities, these enterprises can aggravate or reduce environmental pollution. In the post-COVID-19 era, the definition of sustainable development indicators or achieving a zero-carbon economy should be at the level of SMEs. This is because these enterprises play a significant role in different sectors of the world economy. Without enforcing the target of a zero-carbon economy, national economies cannot achieve this target. In this study, the literature is developed regarding the relationship between SMEs and CO_2 emissions in ASEAN member countries and their power to influence CO_2 emissions in relation to concepts such as industrialisation and globalisation.

3. Theoretical background

It is a common belief that the access to environmental information is quite difficult for SMEs. SMEs' technological skills are lower than those of large companies, and they do not have sufficient capital to spend on environmental issues. Thus, there are major differences between SMEs and large companies. In addition, large companies can issue stocks and use the resulting profits for addressing environmental issues, whereas SMEs do not issue stocks and generally borrow from banks. Consequently, it can be posited that there is no serious pressure on SMEs to care about environmental issues and make improvements to tackle them.

It can be assumed that there are two different production functions based on the size of economies. The first one is for large companies (Equation 1) and the second one is for SMEs (Equation 2).

$$G^{L}\left(Y^{L}, {CO_2}^{L}\right) = F^{L}\ \left(K_L, N_L,\ E_L\right) \tag{1}$$

$$G^{SME}\left(Y^{SME}, {CO_2}^{SME}\right) = F^{SME}\ \left(K_S, N_S,\ E_S\right) \tag{2}$$

In the production functions above, the outputs (Y) and related CO_2 emissions depend on capital (K), labor force (N), and energy (E) as the three major production inputs. Equation 2 can be rewritten as a Cobb-Douglas production function, as shown in Equation 3 focusing on SMEs:

$$G^{SME}\left(Y^{SME}, {CO_2}^{SME}\right) = (K_S)^{\alpha}.(N_S)^{\beta}.(E_S)^{\gamma} \tag{3}$$

where α, β, and γ are the elasticities of the capital, labor force, and energy, respectively.

SMEs try to maximize their profits through output and budget constraints, as shown in Equation 4:

$$\pi^{SME} = Y^{SME} - P_E E_S - rK_S - wN_S \tag{4}$$

The maximization can be run with regard to the three inputs of capital, labor, and energy as in Equations 5-7:

$$\frac{\partial \pi^{SME}}{\partial E_S} = \frac{\partial Y^{SME}}{\partial E_S} - P_E = 0 \tag{5}$$

$$= \gamma \frac{Y^{SME}}{E_S} - P_E = 0$$

$$E_S = \frac{\gamma Y^{SME}}{P_E}$$

$$\frac{\partial \pi^{SME}}{\partial K_S} = \frac{\partial Y^{SME}}{\partial K_S} - r = 0 \tag{6}$$

$$= \alpha \frac{Y^{SME}}{K_S} - r = 0$$

$$K_S = \frac{\alpha Y^{SME}}{r}$$

$$\frac{\partial \pi^{SME}}{\partial N_S} = \frac{\partial Y^{SME}}{\partial N_S} - w = 0 \tag{7}$$

$$= \beta \frac{Y^{SME}}{N_S} - w = 0$$

$$N_S = \frac{\beta Y^{SME}}{w}$$

Banks may allocate loans to SME^{①} and SME^{②}. Therefore, based on the aforementioned production function, K^{①} and K^{②} are the capital of SME^{①} and SME^{②}, respectively (Equation 8):

$$K^{①} = \frac{\alpha^{①} Y^{①}}{r}, \qquad K^{②} = \frac{\alpha^{②} Y^{②}}{r} \tag{8}$$

Generally, banks allocate loans to SMEs based on their marginal productivity of capital. This is the traditional method for allocating loans as is shown in equation (8). Hence, in the process, banks do not pay attention to CO_2 emissions.

The left-hand side of Figure 1 shows the output maximization of two SMEs, namely SME^{①} and SME^{②}. Point "a" denotes the maximized output and shows how a bank allocates loans to two SMEs. Considering CO_2 emissions, the best loan allocation is Point "b". In other words, if the bank only focuses on output and profits, Point "a" will be selected, while considering environmental issues, the optimal becomes Point "b".

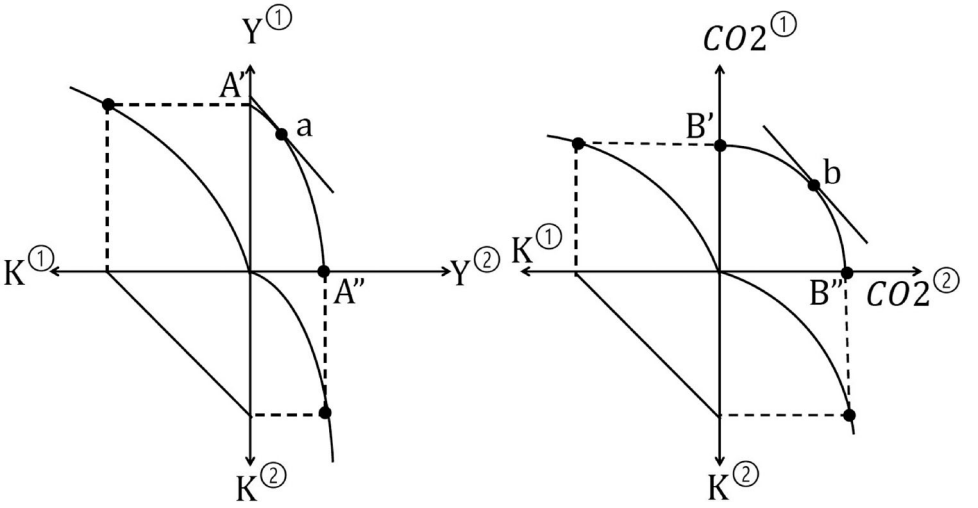

Figure 1. Profit maximisation of SME 1 and SME 2.
Source: Authors' depiction

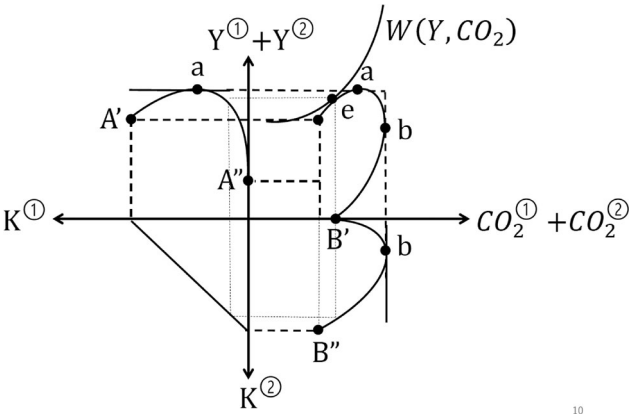

Figure 2. Profit maximisation of SME 1 and SME 2 (mixed approach).
Source: Authors' depiction

If we take into account the output in the second quadrant, the fourth quadrant is CO_2 emissions on Figure 2. $Y^{①} + Y^{②}$ is measured in the second quadrant, and CO_2 emitted by $SME^{①}$ and $SME^{②}$ is measured in the fourth. If we combine the output and CO_2 emissions, then the first quadrant space can be considered. Traditionally, Point "a" is the maximization of outputs and Point "b" is the maximum value of CO_2. We set up an object of environmental issues for SMEs' activities, implying that profit and CO_2 emissions must be considered together. This leads to the selection of Point "e" rather than Points "a" or "b" in the first quadrant. Therefore, it is important to consider how an SME can be led to choose Point "e" compared to other accessible maximized points. This means that banks should consider a function consisting both output and CO_2 emissions (i.e. $W = W(Y, CO_2)$). Thus, banks can allocate loans to SMEs based on green activities. This practical policy by banks will motivate SMEs to promote green activities.

Another matter of this issue is how SMEs can improve their consideration to CO_2 emissions. The importance of company size on tensions to consider the environmental protection. Large companies have pressure from investors, while SMEs do not have investors' pressures. If governments pressure all companies to pay the carbon tax, then theoretically, the best solution regarding environmental tax is Equations 9 and 10. The optimization of profit, as shown in Equation 9, has tax on CO_2 $\{=t(CO2^s)\}$ which reduces the amount of profit of SMEs. Furthermore, γ is a major coefficient depicting improvement of technology which can produce output (Y) and CO_2. In other words, SMEs need to encourage to enhance their energy efficiency and to reduce carbon intensity. However, it requires to be incentivized by the governments through different policies and plans.

$$\pi^{SME} = Y^{SME} - P_E E^s - rK^s - wN^s - t(CO2^s) \tag{9}$$

$$\frac{\partial \pi^{SME}}{\partial E^s} = \gamma \frac{Y^{SME}}{E^s} - P_E - t\frac{\partial (CO2^s)}{\partial E^s} \tag{10}$$

Mathematically, if a SME consider both output and CO_2 emissions in its activity, it has production output of Equations 11 and 12:

$$G(Y^{SME}, CO2^s) = (K^s)^{\alpha}(N^s)^{\beta}(E^s)^{\gamma} \tag{11}$$

$$(Y^{SME})^a (CO2^s)^b = (K^s)^{\alpha}(N^s)^{\beta}(E^s)^{\gamma} \tag{12}$$

Equation 12 can be transformed into logarithmic form as Equation 13:

$$a\log Y^{SME} + b\log(CO2^s) = \alpha \log K^s + \beta \log N^s + \gamma \log E^s \tag{13}$$

The derivations of Equation 13 regarding energy are Equation 14 as follows:

$$\frac{\partial \log(CO2^s)}{\partial \log E^s} = \frac{\gamma}{b} \tag{14}$$

Equation 14 can be reorganized as Equation 15:

$$\frac{\partial (CO2^s)}{\partial E^s} \cdot \frac{\overline{E^s}}{\overline{CO2^s}} = \frac{\gamma}{b} \tag{15}$$

Or:

$$\frac{\partial (CO2^s)}{\partial E^s} = \frac{\gamma}{b} * \frac{\overline{CO2^s}}{\overline{E^s}} \tag{16}$$

The derivation of profit maximization regarding energy is calculated as Equation 17:

$$\frac{\partial \pi^{SME}}{\partial E^s} = \gamma \frac{Y^{SME}}{E^s} - P_E - t * \frac{\gamma}{b} * \frac{\overline{CO2^s}}{\overline{E^s}} \tag{17}$$

Based on the proportion of output to energy, Equation 18 can be calculated:

$$\gamma \frac{Y^{SME}}{E^s} = P_E + t * \frac{\gamma}{b} * \frac{\overline{CO2^s}}{\overline{E^s}} \tag{18}$$

And finally, the optimized amount of energy consumption for an SME can be reached through Equation 19:

$$E^s = \frac{\gamma * Y^{SME}}{P_E + t * \frac{\gamma}{b} * \frac{\overline{CO2^s}}{\overline{E^s}}} \tag{19}$$

If b shows carbon dioxide emissions degree and γ shows energy intensity, then this government policy can help the SMEs to reduce b and γ as well. Equation 13 can be rewritten as Equation 20:

$$alogY^s + b' \log(CO2^s) = \alpha \log K^s + \beta \log N^s + \gamma' \log E^s \tag{20}$$

Where:

$$b' = g(tech'), \quad \gamma' = f(tech') \tag{21}$$

So technological progress $(tech')$ in Equation (21) from large companies to SMEs can be an excellent solution to reduce CO_2 emissions (b') and to lower energy intensity (γ') in Equation (20).

4. Empirical modelling and results

4.1. Data description

Studying the impact of SMEs' activities on environmental pollution is crucial for countries in the post-COVID-19 era, which is the period of economic recovery through SMEs' development and consideration of sustainable economic growth. This study examines this critical issue for ASEAN economies, where GDP growth and sustainable recovery have been prioritised economic plans in the last few decades. CO_2 emissions are selected as a proxy for environmental pollution, and the ratio of the labour force working in SMEs to the country's total labour force was chosen as the proxy for SMEs (explanatory variable of SMEEM). In addition, to derive the long-run linkage between CO2 emissions and SMEEM, four control variables (economic growth, globalisation, industrialisation, and green economic promotion) are added to the econometric model. The existence of a relationship between the selected control variables and CO2 emissions has been confirmed by earlier studies (e.g. Farooq et al. (2022), Huo et al. (2022b), and Liu et al. (2020) for globalization-CO_2 emissions relationship; Mahmood et al. (2020) and Aslam et al. (2021) for industrialization-CO2 emissions relationship; Espoir et al. (2022) and Karaaslan and Çamkaya (2022) for economic growth-CO2 emissions relationship; Dong et al. (2022) and Hao et al. (2021) for green economic promotion-CO2 emissions relationship).

Table 1. Variables' information.

Variable	Symbol	Unit	Source
CO2 emissions	CO	Kilo tons	World Bank, BP
Employees in SMEs/ Total labour force * 100 (ratio)	SMEEM	%	World Bank, ADB, and official websites of ASEAN countries
Globalisation index	KOF	–	KOF Swiss Economic Institute
Industry, value added (% growth)	INDUS	%	World Bank
Global Green Economic Index	GGEI	–	Knoema
Economic growth	ECOGR	%	World Bank, official websites of ASEAN countries

Source: Authors' calculations.

The data for the variables were gathered from different databases for the period–2010–2020. The reason for choosing 2010 as the starting year is that in this study, the global green economy index (GGEI) is considered a proxy for green development introduced in 2010. In addition, the data of some other variables were unavailable for 2021 and 2022, so we had to choose 2020 as the final year to create a balanced data panel for the 10 ASEAN member countries.

The primary information of selected variables is presented in Table 1.

4.2. Econometric equation strategy

According to the selected variables, the initial econometric equation can be written as shown in Equation 9.

$$CO_{i,t} = \alpha_0 + \alpha_1.SMEEM_{i,t} + \alpha_2.KOF_{i,t} + \alpha_3.INDUS_{i,t} + \alpha_4.GGEI_{i,t} + \alpha_5.ECOGR_{i,t} + \varepsilon_{i,t} \quad (9)$$

To determine the best estimation method, it is necessary to examine the nature and characteristics of the data of the selected variables. The first preliminary test checks for the existence of a unit root test. To this end, two popular panel unit root tests augmented Dickey-Fuller (ADF) and Philips-Peron (PP), are employed. If the variables are stationary in the first difference, they may have a long-run relationship. To ensure a long-run relationship, we conduct the Johansen co-integration test in the next step. If the test confirms a long-run connection between the variables, the appropriate estimation framework is the panel co-integration model. In this model, fully modified OLS (FMOLS) is employed to estimate the coefficients of the variables. It is a suitable estimator proposed by Phillips and Hansen (1990) for small sample sizes (Faruque et al., 2022).

4.3. Estimation results

Table 2 reports the results of the three panel unit root test. It shows that all variables become stationary after the first differences, indicating that there may be a long-run relationship between the series.

The aforementioned findings allow the Johansen co-integration test to be conducted. Before performing this test, it is necessary to determine the optimum lag length. To this end, two criteria are used: the (Akaike Information Criterion) and

Table 2. Panel unit root tests.

		CO	SMEEM	KOF	INDUS	GGEI	ECOGR
ADF test	Level	1	1	1	1	1	1
	1st difference	0.002	0.007	0.001	0.004	0.006	0.003
PP test	Level	1	1	1	1	1	1
	1st difference	0.002	0.009	0.001	0.001	0.004	0.006
KPSS test	Level	1.239	−0.032	0.024	0.047	1.202	−0.029
	1st difference	9.392	−2.304	6.172	7.183	10.489	−3.956

Note: CO, SMEEM, KOF, INDUS, GGEI, and ECOGR stand for CO2 emissions, SME employees to total labor force, globalisation index, industry value added, global green economy index and economic growth, respectively.
Source: Authors' calculations.

Table 3. Johansen co-integration test.

Trace			
Hypothesised no of CE (s)	Eigenvalue	Trace stat.	P-value
None*	0.48443	45.1173	0.0060
At most 1	0.30130	14.2912	0.0732
At most 2	0.02192	2.00179	0.1403
Maximum eigenvalue			
Hypothesised no of CE (s)	Eigenvalue	Max-Eigen	P-value
None*	0.48443	22.6038	0.0153
At most 1	0.30130	11.3829	0.0948
At most 2	0.02192	2.00179	0.1143

Source: Authors' calculations.

Table 4. Robustness check of co-integration test.

Statistic	Value
Gt	−1.702**
Ga	−2.283
Pt	−4.392**
Pa	−1.293***

Source: Authors' calculations.

BIC (Bayesian Information Criterion). Table 3 summarises the findings of the Johansen co-integration test.

The results of the co-integration test reveal that there is a single co-integration vector through the trace approach. Therefore, we conclude that there is a long-run relationship between the dependent and explanatory variables.

In addition, the Westerlund co-integration testing is employed as a robustness check for the Johansen co-integration approach. The results of this test, as reported in Table 4, confirm the existence of a long-term relationship among variables.

To determine the signs and magnitudes of the coefficients of the explanatory variables, the FMOLS technique is used, and the following results, reported in Table 5, are explored:

The outcomes of the FMOLS estimation show that any increase in the ratio of employees in SMEs contributes to an increase in CO_2 emissions in ASEAN economies, indicating that SME development in these countries is not in line with the sustainable development strategy. So, the more the amount of labour in small and medium enterprises increases, the volume of production and activity of these enterprises will grow, and this growth will not be in line with sustainable economic

Table 5. FMOLS estimation results.

Variable	Coefficient	P-value
Employees in SMEs/ Total labour force * 100 (ratio)	3.452	0.011
Globalisation index	−1.387	0.885
Industry, value added (% growth)	1.101	0.000
Global Green Economic Index	−0.738	0.0567
Economic growth	3.989	0.003

Source: Authors' calculations.

growth, which will lead to environmental pollution. This finding corroborates earlier studies like Efobi et al. (2019), Yin et al. (2022), and Yan et al. (2022), whereas it contradicts Samargandi and Sohag (2022), and Xiang et al. (2022) who declared the positive role of SMEs in combating environmental pollution. This finding is crucial because one of the most important strategies of ASEAN countries to revive the post-COVID-19 economy is to use the potential of SMEs (ASEAN, 2022, March 21). Based on this study's findings, these countries should adopt other strategies to manage the positive relationship between the development of SMEs and CO_2 emissions, and a greater share of these reform policies and programs should be in line with the development of green activities of small and medium enterprises.

Regarding the globalisation index, the coefficient is negative and statistically insignificant. In other words, there is no long-run statistical relationship between this variable and CO_2 emissions in the ASEAN member states. Despite having a great advantage of globalisation for the development of sustainable development activities of a country, due to the increase of inter-country interactions, the fluidity of ideas and innovation, and the transfer of green technology, the globalisation level of ASEAN has not had any impactful relationship with the reduction of CO_2 emissions in these economies. ASEAN countries can advance the concept of green globalisation (Zhang et al., 2022) by re-politicising the field of globalisation, which will be a factor in the social, economic, and political development of green energy in these countries. These results are in agreement with those of previous studies, such as Farooq et al. (2022), Huo et al. (2022b), and Liu et al. (2020), who discovered a relationship between globalisation and CO_2 emissions.

The estimated coefficient of industrialisation is positive and statistically significant. A 1% increase in the growth of value-added by industry in the ASEAN member states leads to a nearly 1.1% increase in CO_2 emissions. This finding is also important because the progress of the industry sector in ASEAN countries has been significant in recent decades owing to cheap labour, investment from advanced countries, and their geographical location. However, the positive relationship between industrialisation and CO_2 emission shows the lack of sustainable development of these industries. Obsolete technologies, high energy intensity, low energy efficiency, and the dependence of these industries on non-renewable energy inputs are all limitations of the sector, which should be re-planned and politicised in this field.

The green economic indicator has a negative impact on the CO_2 emissions of the ASEAN member states. This means that the policy of greening in the last decade in ASEAN economies was efficient in combating CO_2 emissions, and these states can

follow this efficient policy in the post-COVID-19 era. ASEAN member states should define new incentive tools and financing instruments to promote green economic recovery. Greening economic activities mean increasing energy efficiency in these countries (reducing energy intensity), developing the use of clean energy, and committing to implementing environmental protection standards.

Finally, the estimation results reveal a positive impact of economic growth on CO_2 emissions in ASEAN member states. The coefficient is nearly 3.9, which is the highest among other coefficients. This finding shows a lack of green economic growth in ASEAN countries, and the increase in GDP of these countries is not in line with sustainable and environmentally friendly development indicators. This challenge is important in the post-COVID-19 era, an era of economic recovery and rapid growth. Achieving GDP growth regardless of environmental issues will exacerbate global warming and climate change.

4.4. Robustness check

Two robustness checks are employed to ensure the validity of the aforementioned empirical estimation.

First, an alternative panel co-integration estimator, namely dynamic OLS (DOLS), is used to validate the FMOLS results. To solve the problem of homogeneous slope coefficients in the DOLS estimation technique, we organise the run of the group-mean DOLS estimation approach proposed by Pedroni (2001). The results of this check are presented in Table 6.

As shown in Table 5, the coefficient of the ratio of employees in SMEs is still positive and statistically significant, which proves the validity of our empirical analysis in Table 4.

Next, a robustness check is conducted by replacing the control variables. To run new estimations, inflation rate and urbanisation are used to replace economic growth and the globalisation index, respectively. The results of the second robustness check estimation are summarised in Table 7.

Table 6. Group-mean DOLS estimation results (1st robustness check).

Variable	Coefficient	P-value
Employees in SMEs/ Total labour force * 100 (ratio)	0.043	0.002
Globalisation index	−0.493	0.319
Industry, value added (% growth)	0.002	0.024
Global Green Economic Index	−0.101	0.000
Economic growth	1.203	0.014

Source: Authors' calculations.

Table 7. FMOLS estimation with new control variables (2nd robustness check).

Variable	Coefficient	P-value
Employees in SMEs/ Total labour force * 100 (ratio)	0.011	0.015
Urbanisation	0.024	0.004
Industry, value added (% growth)	0.192	0.131
Global Green Economic Index	−0.039	0.000
Inflation rate	0.004	0.001

Source: Authors' calculations.

By replacing the two control variables, the coefficient of the ratio of employees in SMEs remains positive and significant, indicating the reliability of the empirical findings discussed in Table 4.

5. Conclusions and practical policy implications

5.1. Concluding remarks

In this study, the effects of SMEs on CO2 emissions in ASEAN countries during the period–2010–2020 were investigated. Considering the negative effects of the spread of COVID-19 on the economic activities of ASEAN countries and the need for economic recovery (Taghizadeh-Hesary et al., 2022b) through various programs such as the development of the activities of SMEs, a paradox has arisen regarding the development of SMEs that hampers the sustainable development of ASEAN countries. The results of estimating the coefficients of the explanatory variables using the panel data method showed that the expansion of SMEs is not in line with environmental protection and sustainable development in ASEAN countries because of the positive impact of SMEs on CO2 emissions. Therefore, we can draw an important conclusion that the current development path of SMEs in ASEAN is ineffective in achieving the goal of carbon neutrality, zero carbon economy or green economy, and the development of these enterprises causes more environmental pollution. Another important conclusion is that the growth of GDP and industrialisation in ASEAN economies is not in line with sustainable development goals, and governments should adopt new policies and plans for green transformation in economic growth and industrialisation.

5.2. Policy implications

Based on the study's findings, the following points are suggested regarding strategic and practical policies for ASEAN and similar countries.

First, the application of green financial policies by ASEAN governments can be one of the most important and practical measures in the COVID-19 and post-COVID-19 eras. Incentive facilities (e.g. green financing) for SMEs to develop activities in line with sustainable development and adopting deterrent policies (such as green tax or carbon tax (see Yoshino et al., 2021)) can serve as appropriate solutions for developing the green activities of SMEs in these countries.

Second, another practical policy is to change banks' lending mechanisms to SMEs in ASEAN countries. Banks should, apart from judging the profitability of an SME (ability to repay the instalments of the facilities), assign a score to the green activities of the SME (less emission of greenhouse gases, modernisation of the production line, reduction of energy intensity, and increase of energy efficiency) to grant facilities.

Third, the governments of ASEAN countries should provide expert advice to SMEs to advance activities in line with sustainable development. Establishing free consulting institutions in the field of sustainable development for SMEs can be a suitable strategy for aligning the activities of SMEs to achieve a carbon-free or environment-friendly economy.

Fourth, global and regional integration for technology transfer and green innovative cooperation is another crucial practical policy for the ASEAN member states. According to this study's findings, since industrialisation, the economic growth of these countries has not been in line with the reduction of CO2 emissions. Integration with successful countries in this field at the regional and global levels can be considered a suitable practical policy for ASEAN countries. Such regional and global integration can provide ASEAN countries with successful experiences and suitable growth and industrialisation patterns. In addition, it can lead to more accessible and faster transfer of technology and innovation from developed countries to SMEs in developing ones.

Fifth, lowering the dependency of SMEs on fossil fuels is another practical policy for ASEAN member states. The development of the implementation of the 'energy transition' policy (Rasoulinezhad, 2020) in the activities of SMEs can lead to the diversification of the energy sources used by these enterprises in the medium and long term and reduce the dependence on their production activities on fossil fuels (the primary source of global CO_2 emissions). In this regard, the development of green financing (Rasoulinezhad & Taghizadeh-Hesary, 2022; Taghizadeh-Hesary et al., 2022a) and digital green financing will be a practical policy for the greater participation of the private sector and foreign investors (Phung et al., 2022) in the green projects of SMEs in ASEAN countries.

Sixth, SMEs can employ a business model comprising Corporate Sustainable Responsibility (CSR) to green their activities and performances. CSR improves the contributions of SMEs to sustainable development goals. Through this business model, small and medium-sized enterprises will have a clear roadmap to define sustainable development goals and specify the company's social responsibilities towards the environment.

Seventh, one of the best effective policies for an SME is the consideration of technological progress. The governments can ask large companies to develop technological progress research, buy it as a patent and transfer it to SMEs in ASEAN member states.

5.3. Limitations and recommendations for future research

This study makes a significant and innovative contribution to the literature concerning the relationship between SMEs and environmental protection. However, researchers can conduct more comprehensive and accurate research in this field. For example, considering the variable COVID-19 as a factor affecting the economy and environment can yield more accurate results. In our study, the COVID-19 data for ASEAN countries were not complete and usable; therefore, in the future, using more comprehensive COVID-19 data, this variable can be used as an important explanatory variable in the econometric model.

Another suggestion is to measure the relationship between SMEs and environmental support at the country level. Unlike the panel data model in our research, future researchers can calculate and compare the relationships between variables for each country separately, which can help macro policymakers more effectively. Another suggestion is to use advanced econometric models, such as artificial neural networks and machine learning to predict relationships among variables. The results of these

predictions can help formulate medium- and long-term plans and perspectives on green economic recovery through SMEs for ASEAN countries.

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ORCID

Farhad Taghizadeh-Hesary http://orcid.org/0000-0001-5446-7093

Data availability statement

The data supporting this study's findings are available from the corresponding author upon reasonable request.

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