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Could Renewable Energy Use Boost Goods Export Performance in ASEAN?

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Abstract

ASEAN economic integration has expanded trade opportunities but also contributed to rising carbon emissions, especially from goods exports. ASEAN needs to switch to renewable energy to improve the performance of goods exports. This study analyzes the impact of renewable energy use on goods exports in ASEAN from 2010 to 2020. The findings reveal that renewable energy positively impacts goods export performance. Consequently, it is recommended that governments in ASEAN countries strengthen policies and regulations that incentivize renewable energy use among producers and exporters.

Keywords: goods exports, renewable energy, ASEAN

JEL classifications: O24; O53; Q27

1. Introduction

International trade is an important factor to encourage economic growth (Salvatore 2013). It allows a country to access global markets to sell domestic products and services. As the backbone of the global economy, most international trade occurs via sea routes. It offers key advantages such as high transport capacity and connecting major ports throughout the world (Lun & Marlow 2011; Sunitiyoso et al. 2022). It establishes an interconnected global network and creates economic opportunities for many countries. UNCTAD (2015) discloses that more than 80% of world trade is conducted by sea, with 60% passing through Southeast Asia. The region, intersecting South China Sea, is estimated to support a third of global shipping (UNCTAD 2016). Connected to the Strait of Malacca and the Pacific Ocean, South China Sea becomes a vital maritime route for efficient and fast international trade flows, specifically for Southeast Asia.

Southeast Asian countries united in the Association of Southeast Asian Nations (ASEAN) has fostered economic integration initiatives aimed at promoting economic growth and sustainable cross-border cooperation in the region. The union includes the establishment of the ASEAN Economic Community (AEC) and the issuance of various free trade agreements, such as the ASEAN Trade in Goods Agreement (ATIGA) and the ASEAN Trade in Services Agreement (ATISA). These efforts have significantly improved the international trade performance of the region, as evidenced by the value of exports and imports (Opeyemi et al. 2019; Ilechukwu & Lahiri 2022; Andersen et al. 2023). In the 2010–2022 period, the value of exports and imports in ASEAN exhibited an increasing development trend. In 2022, exports grew by 92%, while imports rose by 99% compared to 2010, demonstrating rapid development over the past decade. Throughout this period, ASEAN consistently recorded a trade surplus. ASEAN is also acknowledged as the 5th largest economy and the 4th largest exporter in the world (ASEAN Indonesia 2023).

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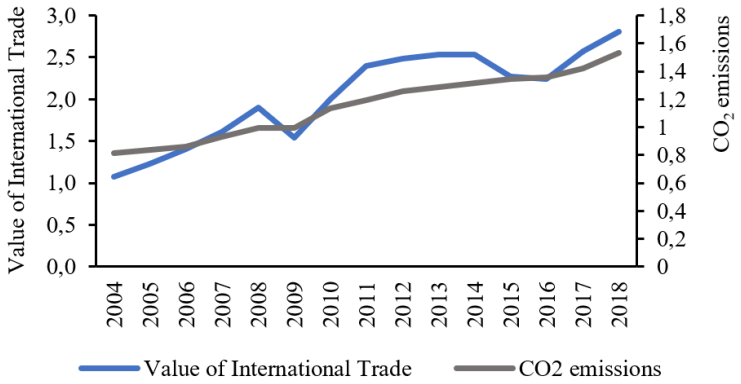

Figure 1. International Trade Value (Trillion USD) and CO_2 Emissions (Thousand Metric Tons) in the ASEAN Region in 2004–2018

Source: Organization for Economic Co-operation and Development (OECD 2021) & World Bank (2023a,d) (processed)

However, the economic benefits obtained by ASEAN countries are also accompanied by a rise in carbon dioxide emissions (Figure 1), which can exacerbate global warming (Anderson, Hawkins & Jones 2016). ASEAN countries, most of which are developing countries, produce more carbon dioxide emissions than developed countries (Wood et al. 2020). More than 90% of the total emissions of the ASEAN region is attributable to Indonesia, Malaysia, the Philippines, Thailand, and Vietnam (Amheka et al. 2022). Observed from 1990 to 2010, carbon dioxide emissions produced by ASEAN countries soared at a faster rate than other countries, rendering ASEAN highly vulnerable to climate change (The ASEAN Secretariat 2023). Around 20–30% of total carbon dioxide emissions in the region are generated by international trade activities (Zhang et al. 2020), with exports contributing more than imports (Salman et al. 2019). Furthermore, carbon dioxide emissions resulting from exports of goods tend to be higher than exports of services due to the production and transportation of goods (WTO 2021). Countries exporting services only send knowledge and expertise rather than physical products (Piaggio, Alcántara & Padilla 2015), hence lower carbon dioxide emissions.

Energy is a critical factor in the production and export processes (Amador 2012). Energy consumption in ASEAN countries has risen between 2010 and 2021, with fossil fuels remaining dominant at 83% in 2020 (ACE 2022). In the long term, reliance on fossil energy to meet energy needs poses environmental risks due to emissions generated (IRENA 2018). To achieve sustainable goods export performance, both economically and environmentally, ASEAN needs to take critical measures, one of which is by switching to renewable energy sources. Compared to fossil energy sources, renewable energy produces lower carbon emissions (Opeyemi et al. 2019). IRENA (2023) predicts that a shift to renewable energy sources can reduce carbon dioxide emissions from the use of fossil energy sources by up to 75% by 2050. It is supported by the ASEAN Declaration on Environmental Sustainability, which was initiated at the 13th ASEAN Summit in 2007, where ASEAN committed to promote the use of renewable energy sources to ensure environmental sustainability in the context of sustainable development. Furthermore, renewable energy can lower production costs by eliminating the need for purchasing fossil fuels. The United Nations (UN) states that renewable energy has become increasingly affordable, with notable price reductions in the last decade. Between 2010 and 2020, the cost of electricity from solar power fell by 85%, while the costs from onshore and offshore wind power decreased by 56% and 48%, respectively.

Several studies highlight that renewable energy use

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has a positive effect on the export performance of several industries in India, where it does not pose a major obstacle to exports (Das & Mahalik 2023). Similarly, several Organization for Economic Co-operation and Development (OECD) member countries are also able to utilize renewable energy without compromising their economic competitiveness (Ilechukwu & Lahiri 2022). Supporting renewable innovation, investment, and infrastructure can solve a myriad of challenges and switching to renewable energy can enhance both sustainability and the economic position of a country in the global market (Opeyemi et al. 2019). Furthermore, erratic fluctuations in the price of fossil energy sources can be detrimental to exporters (Zhang et al. 2021). Although most ASEAN countries still rely on fossil energy sources for their economic activities, they are gradually transitioning to renewable energy. This shift is expected to enhance product competitiveness in the global market and boost the goods export performance of ASEAN countries.

In addition to renewable energy use, other economic variables are considered to influence goods export performance, particularly from the side of exporters. Therefore, goods export activities are explored from the supply side, which is influenced by product prices and production costs (Pindyck & Rubinfeld 2013), exchange rates (Andersen et al. 2023), and raw material imports (Pane & Patunru 2023). Exchange rates are a crucial factor in determining purchasing power and the competitiveness of export products (Khalighi & Fadaei 2017). Raw materials imports open opportunities to obtain quality raw materials to boost exports. Technology influences exports from the supply side (Iswardono 1994). Concurrently, foreign direct investment (FDI) strengthens domestic infrastructure and technology, thereby increasing export capabilities (Andersen et al. 2023).

Previous studies examine the influence of renewable energy use on export performance, yet the analysis remains general and not specific to goods exports. Furthermore, no research has been conducted specifically on ASEAN countries. They only analyze a few types of industry in India (Das & Mahalik 2023) and focus on Sub-Saharan Africa (Opeyemi et al. 2019). Ilechukwu & Lahiri (2022) as well as Jebli & Youssef (2015) only accommodate Gross Domestic Product (GDP) as an additional variable and omit many other economic variables that influence export performance.

Thus, this research aims to determine whether renewable energy use and other economic variables affect the performance of goods exports in the ASEAN region. Focusing on the 2010–2020 period, the research observes trends in renewable energy use in the region. This research is crucial to empirically prove that renewable energy, which generates low carbon dioxide emissions, not only protects the environment but also enhances economic profitability by boosting goods exports. Moreover, the results of this research can serve as valuable insights for stakeholders to formulate effective policies to improve the economy while preserving the environment.

2. Literature Review

An open economic system encourages a country to engage in international trade cooperation to meet the needs of its population and sell goods/services abroad (Rangkuty & Efendi 2022). International trade is an economic relationship between countries that involves the exchange of goods, services and currency to gain profits (Krugman, Obstfeld & Melitz 2018). One of the activities in international trade is export, in which a country produces goods or services needed and sends them to other countries (Mankiw 2013). This research focuses on goods exports. IMF (2009) defines goods as physical objects produced whose ownership rights can be determined and economically transferred from one institutional unit to another through transactions. Accordingly, the World Bank defines goods exports as a change of ownership of all movable goods from residents to non-residents. In general, exports can be analyzed from both demand and supply sides. According to Iswardono (1994), demand for goods

is influenced by price changes, consumer income, price, consumer preferences, and population size. On the other hand, the supply side is influenced by production costs, technology, taxes and subsidies, price expectations, and the number of companies in the industry.

Energy is a crucial element in the economic development of a country (Le & Nguyen 2019), playing a vital role in the production and transportation processes for exports. On the other hand, the relationship between environmental goals and competitiveness is often considered a trade-off, where economic progress compromises environmental sustainability. However, Porter & Linde (1995), through the Porter Hypothesis, argue that strict environmental regulations can foster innovation, boosting the competitiveness of companies/countries in the global market. One such innovation is the shift to renewable energy, which consists of solar energy, water energy, wave energy, wind energy, bioenergy, and geothermal energy (Ang et al. 2022). The use of renewable energy has been proven to bolster the economy, strengthen energy security, and diversify energy consumption (Jebli & Youssef 2015), leading to improved export performance (Costantini & Mazzanti 2012; Lodi & Bertarelli 2023). In addition, renewable energy sources tend to have lower costs than fossil energy sources, making production costs less prone to price spikes as is common with fossil energy sources (Kåberger 2018). Despite these advantages, however, high capital costs associated with renewable energy adoption remain a significant obstacle, often outweighing the results obtained (Nesta, Vona & Nicolli 2014; Opeyemi et al. 2019).

The exchange rate is a factor in trade decisions as it reflects price comparisons between countries (Krugman & Obstfeld 2003). Exchange rates can fluctuate through appreciation or depreciation. Currency appreciation is an increase in the value of a currency, while depreciation is a decrease in its value. This research applied the real effective exchange rate (REER), defined by IMF as the value of a currency against a weighted average of several foreign currencies, divided by a price deflator or cost index. REER can be used to measure the value of a currency of a country relative to others since it incorporates weights based on the relative trade balance with each country included in the currency basket. A rise in REER reflects currency depreciation, rendering export products more expensive. According to supply theory, exporters will increase the quantity of the products sent to partner countries, thus boosting exports.

Foreign direct investment (FDI) refers to international capital flows (Krugman & Obstfeld 2003) and, according to the New Trade Theory, can bolster exports by facilitating the transfer of technology, management, and business practices more efficiently (Helpman 1984). FDI can enhance exports through various means, such as providing additional capital for export production, expanding existing product variety, honing the technical and managerial skills of workers in domestic companies, granting access to global distribution networks to sell in international markets, and improving the export structure of the host country (Ahmad, Draz & Yang 2018; Harding & Javorcik 2011; Rahmaddi & Ichihashi 2013).

Raw materials serve as essential inputs to meet production needs in a country. Referring to the Heckscher-Ohlin theory, a country exports commodities that intensively utilize its abundant and inexpensive resources (Ibrahim & Halkam 2021), while importing necessary raw materials that are unavailable domestically. Therefore, raw materials imports play a crucial role in production needs and influences export performance (Pane & Patunru 2023). Pramiswari & Handoyo (2022) discover that companies importing raw materials have a greater opportunity to bolster exports compared to those that do not. However, fluctuations in raw material prices in international markets can affect production costs. According to supply theory, an excessive import of raw materials, combined with a weakened domestic exchange rate, can raise production costs, causing losses to exporters (Pindyck & Rubinfeld 2013).

In regard to the aforementioned theoretical basis,

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the relationship between variables in this research is described in a framework presented in Figure 2.

3. Method

3.1. Research Scope

This research employed panel data covering an 11-year period (2010–2020) from 10 ASEAN countries, including Brunei Darussalam, Philippines, Indonesia, Cambodia, Laos, Malaysia, Myanmar, Singapore, Thailand, and Vietnam, amounting to a total of 110 observations. The initial period was chosen based on an agreement between the International Energy Agency (IEA) and ASEAN in implementing sustainable energy in the region. Meanwhile, the final period was adjusted to the availability of data, accessible only up until 2020.

The variables used in this research are outlined in Table 1. Real values were applied to analyze growth in value/quantity, eliminating the effect of inflation. The year 2015 was selected as the base year due to its stable economic structure, rendering it suitable as a comparison reference.

3.2. Analysis Methods

The analytical methods applied in this research include descriptive and inferential analyses. Descriptive analysis was employed to provide a general overview of goods export performance, renewable energy use, the real effective exchange rate, foreign direct investment, and raw materials imports in graphical forms. Meanwhile, inferential analysis was utilized to analyze the influence of renewable energy use as well as other economic variables on goods export performance in the ASEAN region. Hypothesis testing for the inferential analysis was performed at a significance level (a) of 5%. Panel data regression was employed as it can accommodate individual diversity and provide more informative data by capturing changes in cross-sectional data throughout the year (Baltagi 2005). Equation (1) represents the general model specification used.

$$\ln EXPORT_{it} = \alpha + \beta_1 RENEW_{it} + \beta_2 \ln REER_{it} + \beta_3 FDI_{it} + \beta_4 \ln IMPR_{it} + u_{it} \quad (1)$$

where $u_{it} = \mu_i + v_{it}$ $EXPORT$ is the real value of goods exports, α is the intercept, $RENEW$ is the percentage of renewable energy use, $REER$ is the real effective exchange rate, FDI is the real value of foreign direct investment, $IMPR$ is the real value of raw materials imports, u_{it} is the one-way error component, μ_i is the individual effect, v_{it}, is the interaction effect, $i = 1, 2, \ldots, 10$ is ten ASEAN countries, and t is the study period (2010–2020). In equation (1), several variables were transformed into natural logarithm forms to reflect the percentage response of the dependent variable to changes in the independent variables (Gujarati & Porter 2009). The stages of panel data regression analysis are as follows:

1. Specifying and establishing three panel regression models: Common Effect Model (CEM), Fixed Effect Model (FEM), and Random Effect Model (REM).
2. Selecting the best model using the Chow test, Hausman test, and BP-LM test.
3. If CEM or FEM is selected, examining the structure of the error variance-covariance matrix using the LM test and λ_{LM} test to determine the estimation method.
4. Conducting classical assumption tests for CEM and FEM with Ordinary Least Square (OLS) estimation: including the error normality test (Jarque-Berra Test), homoscedasticity test (Breusch-Pagan Test), and autocorrelation test (Durbin Watson Test). On the other hand, for REM and FEM with Weighted Least Square (WLS) or Feasible Generalized Least Square with cross-sectional Seemingly Unrelated Regression (FGLS SUR), only the error normality test is conducted. Multicollinearity is examined in all models by observing the Variance Inflation Factor (VIF) values.
5. Assessing the significance of the model us-

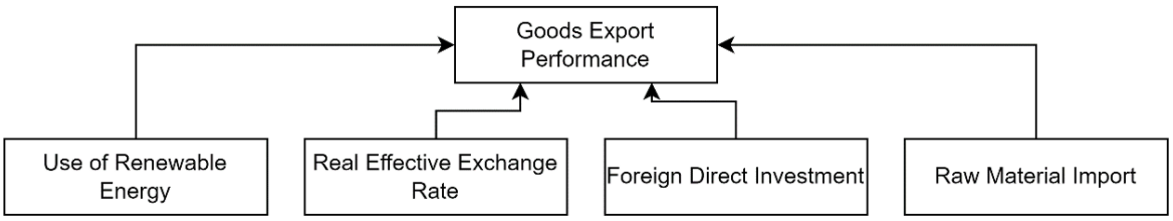

Figure 2. Research Framework

Table 1. Variables, Units, Sources, and Operational Definitions

Variable (1)	Unit (2)	Source (3)	Operational Definition (4)
Goods export performance	billion USD	World Bank	The export value of goods divided by the export value index (2015=100) and multiplied by 100
Use of renewable energy	%	World Bank	The percentage of renewable energy use to total final energy consumption
Real effective exchange rate	-	Bruegel	The effective exchange rate multiplied by the consumer price index of the country being studied and divided by the U.S. consumer price index
Foreign direct investment	billion USD	World Bank	Foreign direct investment inflows divided by the consumer price index (2015=100) and multiplied by 100
Raw materials import (UNCTAD-SoP2 code)	million USD	WITS	The import value of raw materials divided by the import value index (2015=100) and multiplied by 100

ing the coefficient of determination (adjusted R-squared) and the significance of parameters using simultaneous and partial tests.

6. Interpreting the results.

The hypotheses proposed in this research are:

1. The use of renewable energy has a positive impact on goods export performance in the ASEAN region.
2. The real effective exchange rate has a positive impact on goods export performance in the ASEAN region.
3. Foreign direct investment has a positive impact on goods export performance in the ASEAN region.
4. Raw materials imports have a positive impact on goods export performance in the ASEAN region.

4. Results and Analysis

4.1. General Description of Goods Export Performance, Renewable Energy Use, and Other Economic Variables in the ASEAN Region in 2010–2020

The goods export performance of a country can be evaluated by its export value (Kahfi 2016; Ilechukwu & Lahiri 2022; Andersen et al. 2023). A higher goods export value indicates better export performance, as it reflects an increase in the quantity of goods exported. Among the ten ASEAN member countries, Singapore consistently demonstrates the highest goods export performance with an upward trend from 2010 to 2020 (Figure 3). This success is attributed to its intermediate and re-export trade strategies, where the country processes and adds value to imported products then re-exporting them. These products include computers, electronics, and optical devices (Jones et al. 2020). In addi-

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tion, the strategic geographic position of Singapore offers unrestricted access to transportation and trade networks throughout the ASEAN region (Lin & Ewing-Chow 2016). In contrast, Laos exhibits the lowest goods export value, with its exports predominantly focused on the three largest countries, namely Thailand, Vietnam, and China (Stirbat, Record & Nghardsaysone 2015). Observed from 2016 to 2020, the goods export performance of Laos stagnates at only 3.65 billion USD.

As illustrated in Figure 3, the majority of ASEAN countries experience fluctuating developments in the value of goods exports. Singapore and Indonesia see growth in goods export performance, partly driven by the manufacturing industry (Kemendag 2016). On the other hand, Thailand demonstrates a declining trend of goods export performance, primarily due to economic slowdown (Nidhiprabha 2017) and the trade war between the United States and China (Muramatsu 2020). Malaysia also suffers from a decline in goods export performance because of relatively weak investment activities throughout the year and an over-reliance on goods whose value is vulnerable to demand fluctuations (World Bank 2015). Myanmar exhibits a downward trend, particularly in 2010–2019, attributable to difficulties for its exporters in finding consumers (Teachout 2019). Conflict and political instability further weaken the economic activities of the country.

Furthermore, Brunei Darussalam and Cambodia experience increases and decreases in goods export performance in certain years. Brunei Darussalam is highly dependent on oil and gas exports, making its export value highly vulnerable to fluctuations in global oil prices (Chian 2023). Similarly, the high dependence of Cambodia on the United States market and its concentration of exports on certain products and destinations raise its vulnerability to changes in demand and trade policies (World Bank 2017).

According to the ASEAN Plan of Action for Energy Cooperation (APAEC) 2016–2025, ASEAN has set a regional target of achieving 23% renewable energy use by 2025. Four countries have exceeded the target, including Myanmar, Cambodia, Laos, and the Philippines. Myanmar leads in renewable energy use during the 2010–2020 period with an average of 70.36% (Figure 4). The high use of renewable energy comes from traditional biomass for household activities, such as cooking and lighting. In contrast, Brunei Darussalam reports an average of only 0.01% renewable energy use during the same period. As an oil and gas producer, Brunei Darussalam remains focused on exploiting fossil energy sources, resulting in an insignificant contribution from renewable energy to its energy mix.

Figure 4 also reveals that the percentage of renewable energy use in the ASEAN region tends to decrease across many ASEAN countries. Only Malaysia and Singapore exhibit an increasing trend in annual renewable energy use. Conversely, Indonesia gradually fails to meet the target, with renewable energy use dropping from 35.96% in 2010 to 22.0% in 2020. This decline is caused by the continued reliance on petroleum, coal, and natural gas as primary energy sources in Indonesia. Several countries, including Cambodia, face regulatory challenges and lack sufficient financial support (B2B Cambodia 2017). In others, the complexity of responsibility structures among government agencies significantly contributes to inefficiencies in decision-making and delays in obtaining approval in the energy sector (Rahmadi, Hanifah & Kuntjara 2017). Tariffs for installing renewable energy components are also considered very high in certain countries (BloombergNEF 2019). In addition to policy and financial hurdles, seasonal factors also hamper renewable energy use. Despite its substantial hydro energy potential, Laos faced severe drought in the Mekong River in 2019, leading to a drastic reduction of hydropower energy. Vietnam faces a similar challenge, with energy supply declining due to seasonal constraints (UNESCAP 2020). Even the Philippines, with its second-largest geothermal energy potential in the world, sees a downward trend in renewable energy use from unstable tariff settings and limited means to mitigate development risks (Beavers 2018).

On the other hand, Malaysia demonstrates an in-

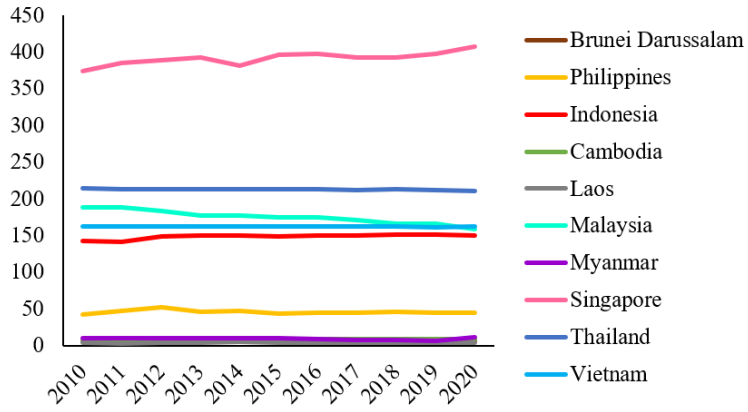

Figure 3. The Development of the Value of Goods Exports in the ASEAN in 2010–2020 (Billion USD)
Source: World Bank (2022, 2023b,c) (processed)

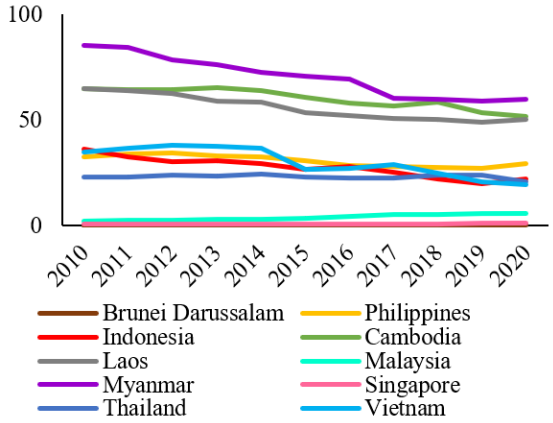

Figure 4. The Development of Renewable Energy Use in the ASEAN in 2010–2020 (%)
Source: World Bank (2022, 2023b,c) (processed)

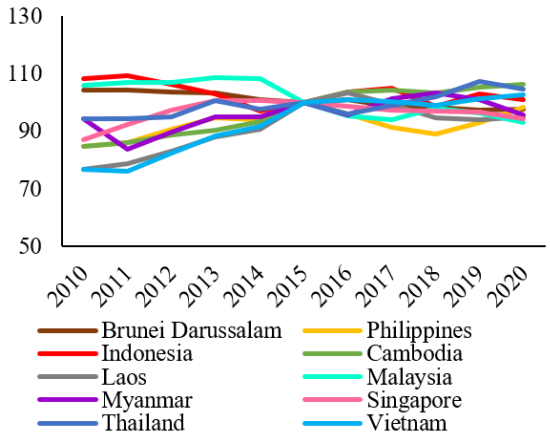

Figure 5. The Development of the Real Effective Exchange Rate in the ASEAN in 2010–2020
Source: Darvas (2021) (processed)

crease in renewable energy use despite its status as an oil and gas producer. This growth is driven by innovations such as the Malaysia Electricity Supply Industry (MESI), which provides environmentally friendly tariffs for consumers, and a 70% green income tax exemption for up to 10 years (UNESCAP 2020). Singapore has the second lowest average use of renewable energy at 0.66%. However, the country has steadily raised its renewable energy use by maximizing solar panels, solid biomass, and biofuels.

As illustrated in Figure 8, most ASEAN countries display parallel developments between renewable energy use and goods export performance. Nevertheless, Indonesia and Malaysia stand as exceptions, in which the rise in renewable energy use reduces the performance of goods exports. Ilechukwu & Lahiri (2022) explain that non-OECD countries such as Indonesia and Malaysia have faced challenges in efficiently implementing renewable energy technologies and managing the associated environmental risks. Conversely, other ASEAN countries maintain a consistent trend between renewable energy use and goods export performance.

In addition to renewable energy use, this research considered other economic variables such as

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exchange rates, foreign direct investment (FDI), and raw materials import. The real effective exchange rate (REER) was applied. As displayed in Figure 5, REER of most ASEAN countries tend to fluctuate from 2010 to 2020, particularly in the Philippines, Indonesia, Laos, Malaysia, and Thailand. Cambodia and Vietnam experience REER appreciation during this period, driven by economic growth in Cambodia (Bao & Le 2022) and increased trade openness in Vietnam (Lien, Doan & Bui 2022). Meanwhile, Brunei Darussalam and Singapore maintain a stable exchange rate, supported by the "Currency Interchangeability Agreement" between the two countries. As illustrated in Figure 8, the majority of ASEAN countries display parallel developments between REER and goods export performance. It reveals that an increase in REER corresponds with improvements in goods export performance.

During the period of 2010–2020, eight of ten ASEAN countries report positive FDI (Figure 6). Brunei Darussalam, however, experiences negative and the lowest FDI in 2016, attributed to oil price fluctuations and reduced domestic market (Stanbic Bank Group 2023). In contrast, Singapore has the highest inflow of FDI, benefitting from its economic capabilities, political stability, technology, and better supervision compared to other ASEAN countries. Several countries observe a decline in FDI inflows in 2020 due to the COVID-19 pandemic. As indicated in Figure 8, the majority of ASEAN countries exhibit parallel developments between FDI and goods export performance. It underscores the significance of FDI to enhance access to international markets and facilitate industries to export their products.

As presented in Figure 7, Thailand is the largest importer of raw materials, as the country does not yield raw materials in large quantities other than natural rubber, gypsum, and cement (Niranatlumpong et al. 2015). On the other hand, Laos has the lowest raw materials imports in ASEAN during the 2010–2020 period because of the abundance of raw materials in the country (Martinico-Perez et al. 2023). A notable development is observed in Brunei

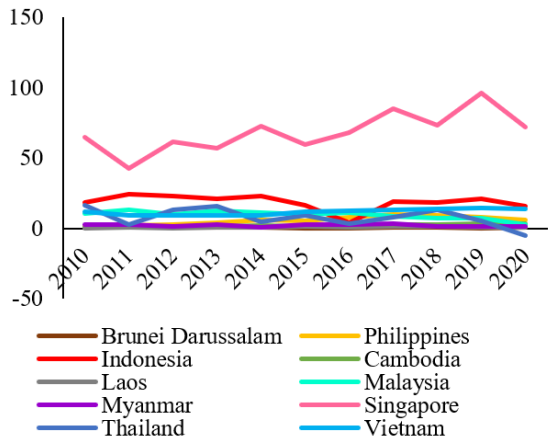

Figure 6. The Development of Foreign Direct Investment in the ASEAN in 2010–2020 (Billion USD)
Source: World Bank (2022, 2023b,c) (processed)

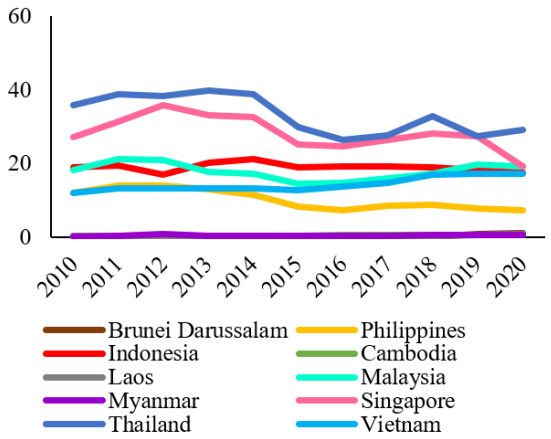

Figure 7. The Development of Raw Materials Import in the ASEAN in 2010–2020 (Million USD)
Source: WITS (2020) (processed)

Darussalam in 2019, where raw materials imports rise by 82.44%, driven by the expansion of its petrochemical manufacturing industry (IMF 2023). Figure 8 illustrates that the majority of ASEAN countries exhibit a positive correlation between raw materials import and goods export performance. By importing raw materials, domestic producers can produce export goods more efficiently and of higher quality, thus improving overall goods export performance. Nevertheless, certain countries such as Malaysia, Myanmar, and Cambodia demonstrate an inverse relationship between raw materials import

and goods export value. This discrepancy may be attributed to import restrictions aimed at protecting local producers (Ardiyanto & Kudo 2020).

4.2. Analysis of the Effect of Renewable Energy Use and Other Economic Variables on Goods Export Performance

Table 2 provides a statistical summary of the dependent and independent variables for the period 2010–2020. The average value of goods export performance (EXPORT) is 116.28 billion USD, with a large variation as evidenced by a standard deviation of 120.79. The average renewable energy use (RENEW) is 30.13, with a range between 0 and 84.93%. The real effective exchange rate (REER) has a relatively stable average of 96.96. Foreign direct investment (FDI) exhibits a negative value of -4.86, obtained by Brunei Darussalam. Lastly, raw materials imports (IMPR) have an average of 12.40, with a standard deviation of 11.90.

Subsequent to specifying the model as in equation (1), tests were conducted to determine the best model between the CEM, FEM, or REM models. The Chow test produces an F-value of 284.8146 and a p-value is 0. Since the calculated F-value is greater than $F_{(0.05;9;96)}$ = 1.98 and the p-value is smaller than the 5% significance level (α), H_0 is rejected. This result indicates the presence of individual effects in the model, rendering FEM more suitable to use than CEM. The Hausman test yields a calculated statistic of 165.1379 and a p-value is 0. Since the calculated statistic is greater than $\chi^2_{(0.05;4)}$ = 9.488 and the p-value is smaller than the 5% significance level (α), H_0 is rejected. It is concluded that there is indeed a correlation between errors and independent variables, thus FEM is determined to be a more suitable model. As FEM is selected as the model, the structure of the error variance-covariance matrix is examined to determine the estimation method.

The LM test generates a statistic of 54.9967 and a p-value of 0. Since the LM calculated statistic is greater than $\chi^2_{(0.05;9)}$ = 16.919 and the p-value is smaller than the 5% significance level (α), H_0 is rejected. It indicates that the structure of the error variance-covariance matrix is heteroscedastic. Similarly, the λ_{LM} test produces a statistic of 80.8728 and a p-value is 0. As the calculated statistic λ_{LM} is greater than $\chi^2_{(0.05;45)}$ = 30.612 and the p-value is smaller than the 5% significance level (α), H_0 is rejected. It confirms a cross-sectional correlation in the error variance-covariance matrix structure. Therefore, the estimation method used for FEM is FGLS with cross-sectional SUR.

Subsequent tests for multicollinearity and error normality were conducted. The results show that the VIF of each variable is less than 10, indicating no multicollinearity. Normality testing using the Jarque-Berra test obtains a statistic of 1.1701 and a p-value of 0.5571. As the statistic is smaller than $\chi^2_{(0.05;2)} = 5,99$ and the p-value is greater than the 5% significance level (α), H_0 is accepted. The estimation results of the selected model are summarized in Table 3.

Referring to Table 3, the adjusted R-squared is 0.9994, which means that 99.94% of the variation in goods export performance in the ASEAN region can be explained by the five independent variables and ten individual units is, while the remaining 0.06% is attributed to factors outside the model. The F-statistic from the simultaneous test suggests that at least one independent variable significantly affects goods export performance in ASEAN. In addition, the partial test reveals that each independent variable has a substantial effect on goods export performance in ASEAN.

The use of renewable energy has a positive and considerable effect on the performance of goods exports with an estimated coefficient value of 0.0049. It means, on average, a 1% increase in renewable energy use leads to a 0.49% rise in the goods export performance of ASEAN countries, assuming other independent variables remain constant. These findings align with the hypothesis of Porter, suggesting that good environmental policies, such as the adoption of renewable energy, do not impede

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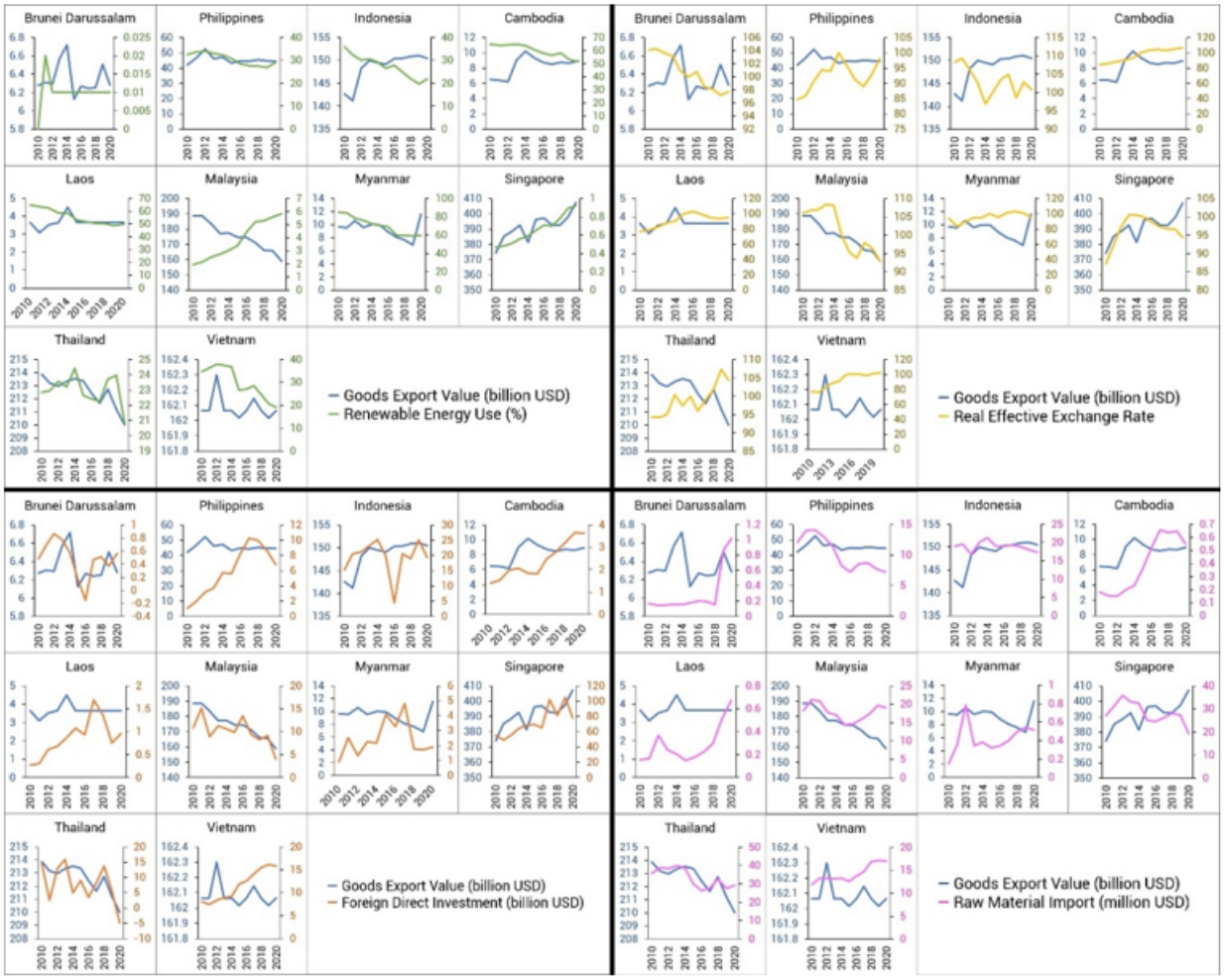

Figure 8. Relationships between Independent Variables and Goods Export Value (Billion USD) in ASEAN in 2010–2020

Source: World Bank (2022, 2023b,c) (processed)

Table 2. Summary Statistical Results

Variable (1)	Minimum (2)	Median (3)	Maximum (4)	Mean (5)	Std. Dev. (6)
$EXPORT$	3.0934	96.7932	407.2605	116.2786	120.7924
$RENEW$	0.0000	27.2500	84.9300	30.1322	24.4056
$REER$	76.1736	98.1784	109.3331	96.9629	7.1722
FDI	-4.8644	5.5077	96.4697	12.7733	20.1544
$IMPR$	0.1443	13.1039	39.8361	12.4037	11.9039

export performance. These findings are also consistent with Das & Mahalik (2023) as well as Keček, Mikulić & Lovrinčević (2019), emphasizing the potential of renewable energy to stimulate national economic growth, especially in exports.

As energy demands for goods exports continue to rise, developing renewable energy innovations is crucial to meet these needs without having exports compromising the environment. Several ASEAN countries have already exceeded regional targets for the use of renewable energy according to their

Table 3. FEM FGLS Estimation with Cross-Sectional SUR Results

Variable	Coefficient	Standard Error	t-statistics	p-value
(1)	(2)	(3)	(4)	(5)
Intercept	1.8914	0.0597	31.7006	0.0000*
RENEW	0.0049	0.0003	18.3161	0.0000*
lnREER	0.3666	0.0115	31.8544	0.0000*
FDI	0.0007	0.0000	13.5672	0.0000*
lnIMPR	0.0490	0.0033	14.9737	0.0000*
Summary Statistics				
R-squared	0.9994	F-statistics	13225.89	
Adjusted R-squared	0.9994	Prob. F-statistics	0.000*	

Note: *) has a significant effect at a significance level (α) of 5%

respective potential. For example, the Philippines capitalizes on its large geothermal potential, Thailand and Laos utilize biomass, while several countries benefit from hydroelectric power plants. By 2030, renewable energy use in ASEAN is expected to double, creating notable opportunities for regional business and investment (IRENA & ACE 2022).

REER has a positive and significant effect on goods export performance, with an estimated coefficient of 0.3666. It implies that, on average, an increase in REER by 1% bolsters the goods export performance of ASEAN countries by 0.3666%, assuming other independent variables remain constant. A rise in REER will render export products more expensive. As a consequence, exporting countries will raise the quantity of products exported, thereby enhancing export performance. These findings are in line with research conducted by Andersen et al. (2023), Thuy & Thuy (2019), and Wahyudi & Anggita (2015).

FDI also has a positive and significant effect on goods export performance with an estimated coefficient value of 0.0007. It suggests that, on average, a one billion USD increase in FDI bolsters the goods export performance of ASEAN countries by 0.07%, assuming other independent variables are constant. These findings align with research by Fernandez, Almaazmi & Joseph (2020), Sahoo & Dash (2022), and Farid et al. (2023), which highlight the critical role of FDI in improving technology and capital, particularly in developing countries. FDI is also essential for promoting renewable energy innovation, as observed in the initiative in Malaysia to attract private investment of 8 billion USD to raise the share of renewable energy to 20% by 2025 (Power Technology 2019).

Raw materials imports have a positive and significant effect on goods exports performance and an estimated coefficient of 0.049. It signifies that, on average, a 1% increase in raw materials imports leads to a 0.049% improvement in the goods export performance of ASEAN countries, assuming other independent variables are constant. These findings are in line with research conducted by Ardiyanto & Kudo (2020), Pramiswari & Handoyo (2022), and Pane & Patunru (2023). Ease of access to raw materials, particularly from developed countries, encourages imports and enhances export performance by improving the quality of final products (Pane & Patunru 2023). ASEAN relies on imports from China for raw materials (Meyer et al. 2021), such as paper (Setyaningrum et al. 2021) and pharmaceuticals (Lathifah 2020). In Table 4, the individual effects obtained from the FEM FGLS estimation with the cross-sectional SUR can illustrate country-specific factors not explained by the variables used in the model. The individual effects capture the differences between one individual and another relative to the average, while the intercept reflects the growth in goods export performance for each ASEAN country.

It is evident that countries with positive individual effects, such as Singapore, Thailand, Malaysia, Vietnam, and Indonesia, have goods export performance above the average when all independent variables are held constant. In contrast,

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Table 4. Individual and Intercept Effects

Rank (1)	Country (2)	Individual Effects (3)
1	Singapore	2.1921
2	Thailand	1.4933
3	Malaysia	1.4148
4	Vietnam	1.2529
5	Indonesia	1.1185
6	Philippines	-0.0003
7	Myanmar	-1.6456
8	Brunei Darussalam	-1.6614
9	Cambodia	-1.7081
10	Laos	-2.4564

countries with negative individual effects such as the Philippines, Myanmar, Brunei Darussalam, Cambodia, and Laos have lower goods export performance under the same condition.

As illustrated in Table 4, Singapore has the highest individual effect at 2.1921, reflecting the strongest goods export performance among ASEAN countries on average when all independent variables are constant. Meanwhile, Laos has the lowest individual effect at -2.4564, indicating the weakest goods export performance among ASEAN countries, falling below the average when all independent variables are considered constant.

5. Conclusion

Between 2010 and 2020, the goods export performance of each ASEAN country shows fluctuating developments. Singapore leads with the best goods export performance, while Laos exhibits the weakest. Malaysia and Singapore also see notable increases in renewable energy use. Other economic variables, such as exchange rates, foreign direct investment, and raw materials imports, reveal similar fluctuations. Referring to FEM with FGLS cross-sectional SUR estimates, the use of renewable energy has a positive effect on the performance of goods exports. It suggests that increasing renewable energy use will bolster goods export performance. Exchange rates, foreign direct investment, and raw materials imports also have a significant effect on goods export performance in the ASEAN region.

Based on these conclusions, the authors recommend that governments strengthen regulations and policies to promote renewable energy use, such as providing incentives for renewable energy users and increasing investment and regional cooperation in research and development of renewable energy technology. These are expected to optimize renewable energy use, particularly in goods export. In addition, governments need to maintain exchange rate stability, facilitate the import of quality and environmentally friendly raw materials, and enhance production capacity. Further research should focus on analyzing the impact of different types of renewable energy to help policymakers identify the most appropriate type of renewable energy to be developed in the ASEAN region.

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