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Chapter: Emergent Perspectives on Green Skills: Driving Change for a Sustainable Future

THE IMPACT OF ECONOMIC OUTCOMES ON SUSTAINABLE ENERGY TECHNOLOGIES IN THE TOP TEN ASIAN COUNTRIES

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Annotation. In terms of maintaining sustainable economic growth, Asian economies share the issues of other developed economies. However, regardless of its status, the region bears the burden of being a high emitter of carbon due to over exploitation of non-renewable resources. The area can maintain its environmental status by switching to renewable energy sources. From 2008 to 2020, this research examines the effects of renewable energy sources on the economy of several Asian countries. Covariate augmented Dickey-Fuller (CADF) and cross-sectional augmented IPS (CIPS) tests for unit root, together with the continuously updated bias-corrected (CUP-BC) and updated full modified (CUP-FM) estimators, are used by researchers to evaluate the correlations. There is a favourable association between producing renewable energy and financial profits, according to the data. Policymakers in the chosen nations should take FDI and GDP into account as important measures of sustainable technology, according to the results. Renewable energy technology might be developed by government agencies in collaboration with the business sector and information and communication technologies (ICT) in order to reduce their dependency on potentially hazardous resources.

Keywords: sustainable energy technologies, exports, energy use, urbanization, foreign direct investment, industrialization, renewable energy, top ten Asian countries.

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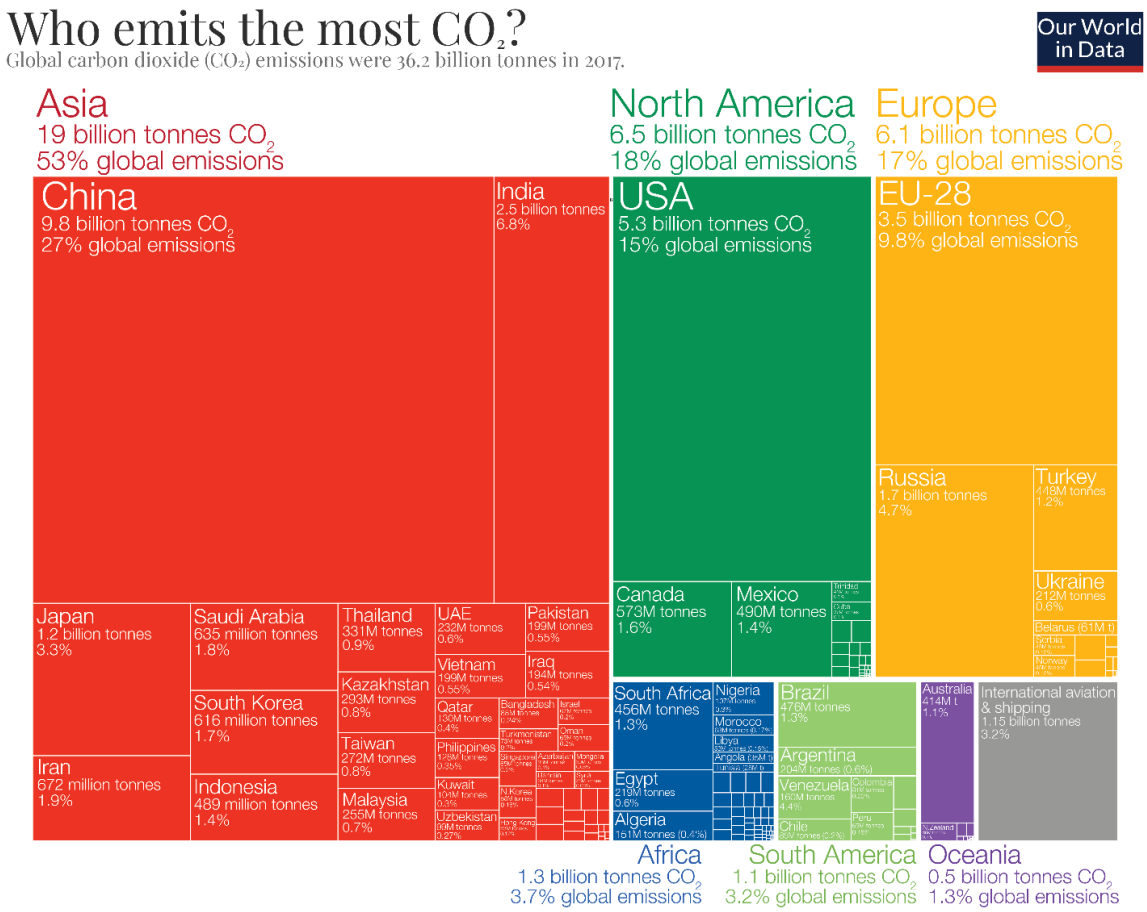
JEL classification: Q01, K32, N7, F63.

Introduction

Changes in the global environment are having a negative impact on businesses and people everywhere. Renewable resources will account for 1.1% of GDP, or about 1.3 trillion USD, by 2030, up from 36% now. By using a significant portion of renewable energy, we can lessen the impact of climate change, boost economic activity, and enhance human welfare in ways that go beyond mere GDP growth. Green energy investments are the same as corporate investments. Vasylieva *et al*. (2019) found a clear correlation between sustainable renewable energy technology and GDP. In addition to GDP, sustainable energy technology impacts intensive and extended export margins. When product quality improves and prices decrease, enterprises export valuable goods to other nations, which boosts the global economy. The whole community commends governments that make the switch to renewable energy. Many export restrictions are lifted, and a plethora of tax benefits are offered. According to Bai*et al*. (2022), a country's reserves grow in tandem with its exports, which has both big and small-scale impacts. citations. When exports exceed imports, it can indicate a robust economy. Both developed and developing economies rely heavily on foreign direct investment (FDI). Unlike other types of businesses, corporations are required by law to have ownership in order to invest abroad. As a means of luring large amounts of FDI, nations should create jobs. According to Streimikiene (2024) and Wall*et al*. (2019), in order to entice international investment, policies should be put in place that promote sustainable energy technologies. two sources. The FDI of many countries declined in 2020 due to the Covid-19 pandemic. It is possible for countries that depend on non-renewable energy resources to have high FDI. Many developing countries are the highest greenhouse gas (GHG) emitters due to their reliance on non-renewable resources, however, with the help of FDI, the dependency can be minimized. It should be easy for countries with high levels of FDI to shift. FDI is obtained when clean energy is used, and FDI helps countries shift to renewable energy technologies (Streimikiene, 2023).

Environmental regulation is essential to achieve sustainable development. The reason being pollution and emission reduction and energy efficiency improvement. Various developed economies inculcated sequential environmental laws and made plentiful investments in order to protect environment (Wall*et al*., 2019; Baziene, Gargasas, 2023). However, environmental regulation and sustainable technologies are tied together depending on certain economic constraints (Mindár, 2024; Chovancova*et al*., 2024). Economies, that highly dependent on economic conditions, are shown more support toward R&D activities and because of this environmental regulation has seen to be worked effectively with stable authority. However, less emerging nations have shown less contribution in such activities because of scarce resources. Thus, creates challenge for economies to indulge in innovative activities (Vasylieva*et al*., 2019). Besides, the limitations also make them less productive in terms of industrial performance, hence, enforcing substantial cost on environment in order to experience positive growth. Moreover, in the absence of external penalty, the energy consuming and pollution-intensive industries swallow more resources and unleash more emissions as they completely neglect environmental costs. Therefore, effective environmental based policies are needed to be developed and implemented to transform industrial structure with the help of sustainable technologies. Through the lens of porter hypothesis, economic outcomes when tied to environmental objectives, promote sustainable technologies and this pressure polluting industries to make improvement in their production processes (Anser*et al*., 2024).

Besides, FDI is one of the elements that creates potential growth through employment creation and resource transformation that stimulates productivity, enhance skills and increase knowledge. FDI inflows are also pivotal that equip economies to remain sustainable in global competition. Literature illustrates two crucial opinions regarding FDI inflows (Zhao*et al*., 2022). First, FDI is believed to have the technology spillover impact which certainly improve environmental quality with the help of "pollution abatement, energy efficient, clean energy and pollution management technologies". As per the view, pollution halo hypothesis is supported. The later view articulates that FDI effects environment negatively as it increases emissions, hence, the said view supports pollution hypothesis. As per the view, organizations find ways to get away from rigid environmental policies, thereby, they shift their production from strict environmental regulation to weak one (Anser*et al*., 2025). Thus, sustainable technologies are viewed as a savior due to their potential of establishing considerable economy and environment. Most of the nations, especially developed ones have taken measures to embrace sustainable technology in their pollution intensive industry in order to safeguard environment through emission reduction, however, the technology adoption appears to be temporary due to high cost and lack of support. Thus, serious measures must be taken to realize the potential benefits of sustainable technologies. The argument raises question that how supportive economic related outcomes are for sustainable technologies? Do the outcomes encourage sustainable technologies or intimidate the buildup?

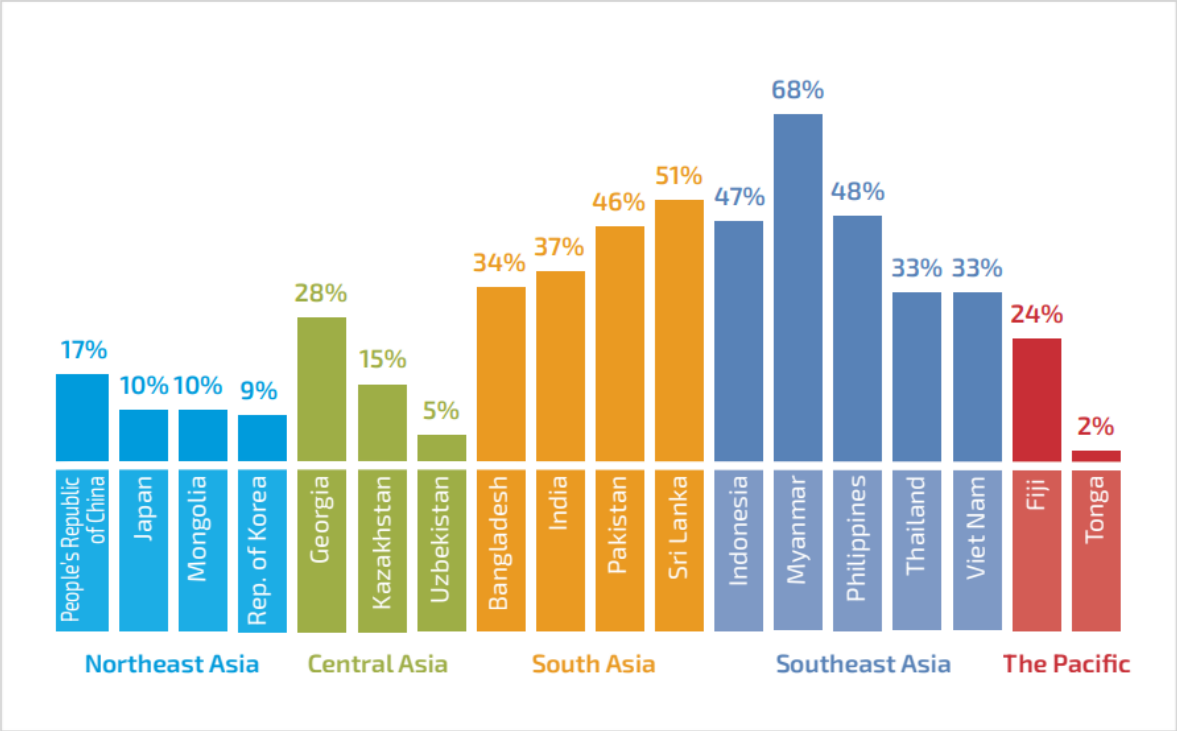


Source: https://ourworldindata.org/grapher/annual-co-emissions-by-region

Figure 1. **Carbon Emission Trends by Region and Country**

Economies are in a constant struggle to address the dual challenge of maintaining economic growth and confronting environmental problems. The struggle is more evident in the Asian context, for various reasons. In 2019 the Asian region experienced a 5% increase in GDP growth; however, the growth went into decline of -0.2% in 2020 due to the pandemic. In 2021, the region was projected to see 7.3% GDP growth, and 5.3% in 2022. The region is recognized as one of the fastest growing economically, and, to maintain its ranking, it is accountable for fossil fuel consumption to cover the region's energy needs. The high economic growth demands high energy consumption, hence high emissions, and climate disruption. Asian economies are responsible for 52% of carbon emissions, making the region the biggest GHG emitter (Luo*et al*., 2021). This study considers 10 Asian economies: China, India, Bangladesh, Indonesia, Malaysia, Pakistan, Thailand, Vietnam, South Korea and Philippines. The sample is carefully selected for a variety of reasons. Both China and India are high emitters of GHGs and leading trading economies. China alone accounted for 28.6% of manufacturing output in 2019, ranked number 1 of all economies. India, Indonesia, and South Korea are in 5th, 10th and 6th positions, and are considered large producers of manufactured goods. India, Pakistan and China are highly populated. Energy production from sustainable energy technologies is still in its initial stages in Indonesia, but the government is starting to reduce its carbon footprint from conventional electricity generation by introducing new policies for sustainable energy and helping investors to invest in sustainable energy technologies. In Laos, an increase in population, the proximity of cities, and climatic change have all lead to a surge in energy demand, and the government is shifting towards cheaper and more sustainable energy production (Shibli*et al*., 2021). The Malaysian state government is looking at more renewable energy production, but currently only produces 2% of its energy from renewable sources. The establishment of hydropower stations to achieve a target of 20% of energy coming from renewables by 2025 is a major part of their policy. Philippines is in a transitional phase towards sustainable and renewable energy production. Photovoltaic cells as solar generators are the pillar of their electricity generation system. By 2050, it is predicted there will be a 20 to 55 billion Euro investment in heat pumps, solar cells, and other renewable energy technologies (Adedpyin*et al*., 2021). Thailand’s energy sector contributed 77% of its total carbon emissions in 2016. Subsequently, the Thai government has taken steps to include renewable energy in its power sector, using solar and hydropower generation technologies. It has a target to achieve 20% renewable energy. In Vietnam, the government aims to ensure national energy security by synchronizing renewable energy resources and energy sub-sectors to achieve set goals by 2030 (Azam*et al*., 2021; Azam, Haseeb, 2021).

The situations in the selected economies indicate that all these countries have the potential to use sustainable technologies to produce renewable energy (Amin*et al*., 2020). These countries are progressing in terms of economic and industrial development. They are all seeing rapid growth in their populations, meaning primary energy use, from fossil fuels, is increasing constantly. This makes the environment more polluted and economies less efficient in terms of sustainability (Lin*et al*., 2022). The ultimate solution for Asian economies is to shift to sustainable, renewable technologies. Shifting to a zero-carbon economy resolves issues related to social health and strengthens the industrial base through innovation, eventually ensuring long-term economic sustainability and achieving the Paris Agreement goal of a zero-carbon society by 2030 (Sadiq*et al*., 2024; Kamarudin*et al*., 2021).



Source: created by the authors.

Figure 2. **Share of Renewable Energy in the Total Energy Mix by Region, 2016**

The present study uses a fresh data set of 10 Asian countries to evaluate the association between economic growth, exports, energy use, urbanization, FDI, industrialization and sustainable energy technologies. The study, thus, contributes by providing empirical evidence for the region which can be treated as a baseline for other economies. The sustainable production and distribution of resource-intensive goods is vital for Asian economies; thus, the present work examines the economic complexity so that better environmental policies can be developed. As discussed, the region is responsible for high fossil fuel consumption. Against this backdrop, the work is pioneering, as we examine all the critical factors in a single framework in order to explore their effect on the sophisticated sustainable technology on which the production of complex products that benefit economies and environments simultaneously depends. The study applies long-run estimators such as CUP-FM which can address panel data issues such as cross-sectional dependence (CSD), endogeneity, heteroscedasticity, and residual correlation. The findings are verified using the CUP-BC method, making this investigation unique in generating authentic evidence to facilitate the design of efficient environmental policies in the selected economies.

The paper continues with a literature review which offers theoretical and empirical insight, followed by the methodology which explains the method and tools adopted. Finally, the results are presented and contrasted with previous literature and, in light of the evidence, recommendations and proposed policies are defined to conclude the study.

1. Literature Review

The progress of any country is tied to its economic growth. As growth comes from industry, we can say it has a relation to industrial procedures and the technologies used to produce goods and services. There is an association between energy use, energy production, and economic prosperity (Banday, Aneja, 2020). Simionescu *et al*. (2019) explore sustainable energy technologies in the European Union from 2007 to 2017, and confirm that GDP is significantly tied to sustainable energy technologies. Bekhet and Othman (2018) explore the association between sustainable energy technologies and GDP in Malaysia, using the CUSUM method, and recommend that Malaysian policymakers develop an energy policy which ensures a balance of economic growth and environmental prosperity. Dabboussi and Abid (2022) produce similar results. Hence, we can conclude that the world must switch to sustainable energy technologies with the aim of supporting the world environment and economy, leading to the first hypothesis:

H1: There is an association between GDP growth and sustainable technologies

There are a number of factors that can help the economy to grow through sustainable development, exports being one. An increase in exports brings cash into a country, which helps the business community, thereby helping the common society by providing jobs (Bao, Xu, 2019; Chen*et al*., 2019b). According to research by Rahman*et al*. (2022), exports boost commodity output, which forces more industrialisation, worsens environmental conditions, and calls for more sustainable energy sources. two places. Remittances are an undervalued source of input that might aid in reducing environmental harm; this is despite the present flood of research into public finance and financial development (FD). There is a lack of study on the topic of education and export diversification, and the studies that have been conducted have shown mixed results. After taking renewable energy and economic development in the top remittance-receiving nations into consideration, Zafar *et al*. (2022) investigate remittances, export diversification, education, and carbon dioxide emissions as factors. Their research shows that remittances help the environment by decreasing pollution levels. Similar findings are produced by Zhang *et al*. (2025) in their research on exports and renewable energy.

H2: There is an association between exports and sustainable technologies

Globalisation has caused an explosion in the need for energy. Businesses are driven to grow as a result of the increased need for energy and equipment caused by bigger industries. Carbon emissions are harmful to the environment and are produced by conventional energy generation methods. Degradation of the environment has made it imperative that, to achieve environmental sustainability, the globe switch to renewable energy sources. Hence, sustainable energy technology, which includes renewable energy sources, is related to energy consumption (Chen*et al*., 2019). A and B. Communities give up their traditional ways of life and their resources when they are compelled to do so in order to stay stable. To be considered sustainable, technology must harness energy from renewable sources that are safe for humans and the environment. Zhang*et al*. (2025) found that increasing energy use results in increased carbon emissions, hence there is a growing demand for sustainable energy solutions. Also utilising a panel estimate approach, Inglesi-Lotz and Dogan (2018) assess the energy consumption and renewable energy technologies of African countries. Since increasing energy consumption results in more carbon emissions, sustainable energy solutions are in high demand.

H3: There is an association between energy use and sustainable technologies

The requirement for energy has increased dramatically as a result of globalisation. The rising need for energy and equipment generated by larger industries propels businesses to expand. Traditional energy sources release carbon emissions, which are bad for the planet. The world must immediately transition to renewable energy sources in order to attain environmental sustainability in light of the mounting environmental degradation. Thus, energy consumption is associated with sustainable energy technologies, such as renewable energy sources (Chen*et al*., 2019). Two options, A and B. In times of crisis, communities often abandon their ancient practices and valuable resources in order to maintain stability. For technology to be deemed sustainable, it must be able to draw energy from non-polluting and environmentally friendly renewable sources. An increasing number of people are looking for renewable energy sources since studies by Zhang*et al*. (2025) show that rising energy use leads to higher carbon emissions. The energy consumption and renewable energy technology of African nations are evaluated by Inglesi-Lotz and Dogan (2018), who also use a panel estimate technique. Sustainable energy solutions are highly sought after since rising energy usage leads to higher carbon emissions.

H4: There is an association between urbanization and sustainable technologies

There are several ways in which foreign direct investment (FDI) contributes to economic growth. One of these methods is by reducing the trade deficit and boosting international trust in the country. As a result of FDI-driven company expansion, energy consumption in manufacturing rises. The utilisation of renewable energy, financial development, foreign direct investment (FDI), and economic growth of the United Arab Emirates (UAE) are examined by Samour *et al*. (2022) from 1989 to 2019. The report summarises the key findings and discusses the implications for policymakers based on the estimation methods used. The data strongly backs up the claim that FD, FDI, and economic development significantly boost the use of renewable energy sources. Financial risk endangers market stability and reduces the adoption of renewable energy sources; so, encouraging financial development is critical for minimising this risk. Carbon dioxide emissions, renewable energy, and non-renewable energy are examined in 69 Belt and Road initiative countries by Khan *et al*. (2021), who also examine the implications of financial investments, foreign direct investment, and technological breakthroughs. The results demonstrate that foreign direct investment (FDI), economic development, and technology advancement have a detrimental effect on renewable energy. On the other side, the renewable energy industry greatly benefits from financial development. As their economies grow, attract foreign direct investment, and develop new technologies, the BRICS countries reduce their energy usage and carbon emissions. Funding, technological innovation, renewable energy, and foreign direct investment (FDI) all show a positive correlation in the Granger non-causality test. The report argues that the BRICS countries' financial markets should be bolstered as they are the engine that propels the renewable energy industry and, by extension, renewable energy in general, which lowers emissions of carbon dioxide. Research and development of technological advancements need major financial backing for these nations.

H5: There is an association between FDI and sustainable technologies

Products and services must be delivered to doorsteps worldwide. The environment is being affected by industrialisation and carbon emissions as a result of the growing population and increased product consumption (Sadiq *et al*., 2024). Amri (2019) uses data from 72 nations spanning 1990–2012 to examine the relationship between renewable energy and industrialisation. The findings demonstrate that renewable energy sources are significantly impacted by industrialisation. In order to optimise output with

minimal input of time and effort, industrialisation has led to a growth in the usage of technology, namely equipment. Clean energy is in great demand since an increase in machinery equals an increase in carbon emissions. The link between industrialisation and sustainable energy technology is explored by Wang *et al*. (2020). Carbon emissions, they say, are rising in tandem with industrialisation, and this is what really drives the need to discover renewable energy sources. Many national governments are promoting the use of renewable energy sources as a means to mitigate the effects of climate change. But not all countries can adequately use renewable energy sources, and inefficient usage of these resources can make environmental harm worse instead of better. According to Kahouli *et al*. (2022), who examined the connection between industry and climate change, renewable energy may help mitigate the negative effects of industrialisation on the environment.

H6: There is an association between industrialization and sustainable technologies

2. Methods and Materials

Using data on renewable energy output, GDP growth, exports, urbanisation, foreign direct investment, and industrialisation, this article examines the top ten Asian nations. The nations that were chosen were those that had the most rapid increase in their gross domestic product: the Philippines, India, Bangladesh, Indonesia, Malaysia, Pakistan, Vietnam, Thailand, and South Korea. The time period for the study is 2008 to 2020. The article develops the following equation for the variables under study:

$$REP_{it} = \alpha_0 + \beta_1 GDPG_{it} + \beta_2 EXP_{it} + \beta_3 EU_{it} + \beta_4 IND_{it} + \beta_5 FDI_{it} + \beta_6 URB_{it} + e_{it} \quad (1)$$

We apply descriptive statistics to check the details of the variables. A matrix of correlation is used to check the directional nexus among the constructs. We check the cross-sectional dependence (CSD), because substantial interdependencies exist, especially when the cross-section or time dimension is large. The CSD is examined using three tests, the Breusch-Pagan LM, Pesaran scaled LM, and Pesaran CD tests. The equation for BP-LM is given as:

$$\boldsymbol{LM_1 = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T_{ij} \hat{\rho}_{ij}^2 \rightarrow X^2 \frac{N(N-1)}{2}} \quad (2)$$

The equation for the PS-LM test is given as:

$$\boldsymbol{LM_2 = \sqrt{\frac{1}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \left(T_{ij} \hat{\rho}_{ij}^2 - 1\right) \rightarrow N(0,1)} \quad (3)$$

Finally, the equation for the Pesaran CD test is given as:

$$\boldsymbol{CD = \sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T_{ij} \hat{\rho}_{ij}^2 \rightarrow N(0,1)} \quad (4)$$

where, $\rho\hat{}_{ij}$ is the correlation coefficient.

We also apply the CADF and CIPS tests to examine the unit root among the variables. The null hypothesis is that the exposed panel has a unit root while the alternative hypothesis is that the exposed panel has no unit root. The CADF calculation that determines the stationarity is given as:

$$\boldsymbol{y_{it} = \alpha_i + b_i y_{it-1} + c_i \bar{y}_{it-1} + d_i \Delta \bar{y}_t + e_{it}} \quad (5)$$

The CIPS test is used to examine the stationarity of the series. The null hypothesis is that the exposed panel has a unit root while the alternative hypothesis is that the exposed panel has no unit root. The CIPS test can deal with CSD and offer accuracy in the results. The CIPS equation is:

$$\Delta \boldsymbol{W}_{i,t} = \emptyset_i + \emptyset_i \boldsymbol{Z}_{i,t-1} + \emptyset_i \overline{\boldsymbol{Z}}_{t-1} + \sum_{l=0}^{p} \emptyset_{il} \Delta \overline{\boldsymbol{W}}_{t-1} + \sum_{l=0}^{p} \emptyset_{il} \Delta \boldsymbol{W}_{i,t-1} + \boldsymbol{\mu}_{it} \quad (6)$$

where $\overline{W}$ is the average cross-section, given as:

$$\boldsymbol{W}^{i,t} = \emptyset^1 \overline{\boldsymbol{ENT}}^{i,t} + \emptyset^2 \overline{\boldsymbol{EINO}}^{i,t} + \emptyset^3 \overline{\boldsymbol{RE}}^{i,t} \quad (7)$$

The CIPS test statistic is:

$$\widehat{\boldsymbol{CIPS}} = \boldsymbol{N}^{-1} \sum_{i=1}^{n} \boldsymbol{CADF}_i \quad (8)$$

We scrutinize the co-integration using the Westerlund and Edgerton (2008) co-integration approach. This approach uses the LM bootstrap integration strategy to produce two statistics, given as:

$$\boldsymbol{LM}_{\boldsymbol{\varphi}}(\boldsymbol{i}) = \boldsymbol{T}\widehat{\boldsymbol{\varphi}}_{\boldsymbol{i}} \left(\hat{\boldsymbol{r}}_{\boldsymbol{i}}/\hat{\boldsymbol{\sigma}}_{\boldsymbol{i}}\right) \quad (9)$$

$$\boldsymbol{LM}_{\boldsymbol{\tau}}(\boldsymbol{i}) = \widehat{\boldsymbol{\varphi}}_{\boldsymbol{i}}/\boldsymbol{SE}(\widehat{\boldsymbol{\varphi}}_{\boldsymbol{i}}) \quad (10)$$

where $\widehat{\boldsymbol{\varphi}}_{\boldsymbol{i}}$ is the φ_i approximation against σ_i standard error, and r^2_i denotes the long-run assessed variance of $_{it}$, $\boldsymbol{\varphi i}\ (\boldsymbol{L}) = 1 - \sum \boldsymbol{\varphi}_{ij}\boldsymbol{L}^j$ signifies a scalar polynomial with L lag length, and ρ_i signifies the factor loading parameter vector.

We also apply CUP-FM and CUP-BC to examine the links among the constructs. The CUP-FM estimator is created by factor loadings, continuous parameters, and covariance matrix estimation until convergence is attained. The CUP-FM and CUP-BC equation is given as:

$$\boldsymbol{\beta}_{\boldsymbol{cup}} = \left[\sum_{i=1}^{N}\left(\sum_{t=1}^{T} \widehat{\boldsymbol{y}}_{\boldsymbol{it}} + \widehat{\boldsymbol{\beta}}_{\boldsymbol{cup}})(\boldsymbol{x}_{\boldsymbol{it}} - \overline{\boldsymbol{X}}_{\boldsymbol{i}})' - \boldsymbol{T}\left(\boldsymbol{\lambda}'_{\boldsymbol{i}}(\widehat{\boldsymbol{\beta}}_{\boldsymbol{CUP}})\hat{\Delta}_{\boldsymbol{F\varepsilon i}}(\widehat{\boldsymbol{\beta}}_{\boldsymbol{CUP}}) + \hat{\Delta}_{\boldsymbol{u\varepsilon i}}(\widehat{\boldsymbol{\beta}}_{\boldsymbol{CUP}})\right)\right)\right] \times \left[\sum_{i=1}^{N}\sum_{t=1}^{T}(\boldsymbol{x}_{\boldsymbol{it}} - \overline{\boldsymbol{X}}_{\boldsymbol{i}})\ (\boldsymbol{x}_{\boldsymbol{it}} - \overline{\boldsymbol{X}}_{\boldsymbol{i}})'\right] \quad (11)$$

where $\hat{\Delta}_{\boldsymbol{F\varepsilon i}}\boldsymbol{and}\ \hat{\Delta}_{\boldsymbol{u\varepsilon i}}$ are one-sided estimated covariance. The CUP-BC and CUP-FM techniques provide significant findings in the case of exogenous variables. Moreover, CUP-FM and CUP-BC provide robust estimations and are suitable when the integration orders are I(0) and I(1). These methods offer robust estimations even though heteroscedasticity, autocorrelation, and endogeneity issues exist (Bai, Kao, Ng, 2009). Additionally, these evaluation methods have reasonable size values and are suitable for studies with small sample sizes. Finally, these methods are frequently applied when researchers examine long-term associations (Fang, Chen, 2017; Ulucak, 2020).

3. Study Findings

Table 1 shows that the REP average value is 14.058% while GDPG is 3.44%, EXP is 29.968%, and EU is 2650.802 kg of oil. The URB mean value is 2.056, FDI is 1.529 %, and IND is 35.051%. The study takes 130 observations (13 years x 10 countries). *Table 1*, below, presents these figures.

Table 1. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
REP	130	14.058	10.473	0.000	36.636
GDPG	130	3.442	3.897	-7.445	13.396
EXP	130	29.968	16.468	8.257	71.416
EU	130	2650.802	2004.366	437.241	7457.369
URB	130	2.056	0.979	-0.249	3.709
FDI	130	1.529	1.306	-0.966	8.496
IND	130	35.051	10.104	17.721	66.757

Source: authors' estimation.

Renewable energy output is positively and statistically significantly related to the following factors among the top ten Asian countries: GDP growth, exports, energy consumption, urbanisation, FDI, and industrialisation (*Table 2*).

Table 2. Correlation matrix

Variable	REP	GDPG	EXP	EU	URB	FDI	IND
REP	1.00						
GDPG	0.213	1.00					
EXP	0.580	-0.019	1.00				
EU	0.708	-0.236	0.407	1.00			
URB	0.248	0.383	0.032	-0.368	1.00		
FDI	0.040	0.309	0.279	-0.069	0.512	1.00	
IND	0.615	0.151	0.472	0.522	0.320	0.430	1.00

Source: authors' estimation.

The three CSD test and results given in Table 3 indicate that no CSD exists.

Table 3. Correlation matrix

Variable	Breusch-Pagan LM	Pesaran Scaled LM	Pesaran CD
REP	43.902***	34.985***	12.915***
GDPG	52.091***	37.882***	12.880***
EXP	28.981***	32.948***	3.771***
EU	41.097***	73.920***	5.883***
URB	31.984***	43.920***	11.262***
FDI	22.899**	77.927***	7.983***
IND	10.092***	62.360***	13.257***

Source: authors' estimation.

According to *Table 4*, which displays the findings of the unit root test, FDI, EU, URB, and REP are stationary at I(0), whereas EXP, IND, and REP are stationary at I(1).

Table 4. CADF and CIPS unit root tests

Variable	CIPS		CADF	
	Level	1st Difference	Level	1st Difference
REP	-1.321	-4.242***	-1.431	-4.773***
GDPG	-2.367***	-5.898***	-3.833***	-6.854***
EXP	-1.532	-3.982***	-1.182	-3.628***
EU	-3.892***	-7.376***	-4.761***	-7.817***
URB	-4.737***	-5.878***	-3.874***	-6.467***
FDI	-3.892***	-6.736***	-2.988***	-5.892***
IND	-0.392	-3.324***	-1.139	-3.102***

Source: authors' estimation.

Westerlund and Edgerton (2008) put forth the methods that we use to investigate the co-integration. There is evidence of co-integration since both the t-statistic and the p-value fall inside the permissible range. The figures are shown in *Table 5*.

Table 5. Co-integration test

Model	No Shift		Mean Shift		Regime Shift	
	Test Stat	p-value	Test Stat	p-value	Test Stat	p-value
LM_{τ}	-4.902	0.000	-4.382	0.000	-8.021	0.000
LM_{ϕ}	-4.817	0.000	-5.773	0.000	-5.772	0.000

Source: authors' estimation.

Table 6. CUP-BC and CUP-FM tests

Variables	CUP-FM		CUP-BC	
	Coeff	t-stat	Coeff	t-stat
GDPG	0.673***	3.892	0.629***	2.998
EXP	0.872***	3.334	0.652***	3.028
EU	0.674***	5.102	1.899***	5.983
URB	0.763***	4.873	1.902***	5.291
FDI	1.093***	5.299	0.382***	2.775
IND	1.982***	3.720	0.567***	4.653

Source: authors' estimation.

Table 6 shows that among the top ten Asian nations, renewable energy output is positively and statistically significantly correlated with economic outcomes such as GDP growth, exports, energy consumption, urbanisation, foreign direct investment, and industrialisation.

4. Discussion

The study shows the findings that there is an increase in the production of renewable energy production. This is quite convincing, because when a country has a high GDP, the requirement for energy increases, there is a trend to transit to renewable energy, and investment resources are large, so renewable energy production is high. Chen et al. (2019) and Olabi (2019) imply that, when a country makes rapid progress, all economic sectors tend to accelerate the level of production to present more goods and services in the market, and the need for energy increases. When the established pattern of energy production is unable to fulfil the energy needs, firms tend to use renewable energy. The increasing demand results in increasing renewable energy production. Magazzino et al. (2021) suggest that, in an economic period

when there is high GDP, firms tend to boost production. In this situation, energy is required for various technologies. The excessive need for energy is fulfilled by the production of renewable energy.

The findings show that renewable energy production is enhanced by exports. It is reasonable to do so since producing renewable energy may satisfy the substantial energy requirements of exporting products and services. Countries may invest their tax money in sustainable technology, driving up demand for renewable energy and related technologies (Bamati, Raoofi, 2020, p.12). After then, renewable energy production increases. Growing exports reduce a country's reliance on finite, non-renewable energy sources and boost its ability to produce renewable power (Vural, 2021, p.64).

According to the results, renewable energy production is positively correlated with energy consumption. As a population grows, so does the amount of energy used by households, and more people tend to be socially active. Power generation from long-term, sustainable sources becomes crucial when demand reaches a particular level. The results are in line with the study of Sinha and Shahbaz (2018), who discovered that the more cars on the road, the more energy is used. When fossil fuels like gas, coal, and oil are unavailable or too costly, renewable energy must be used to power transportation. Renewable energy sources are so increased in production. York and Bell (2019)) conclude that traditional energy sources including coal, oil, gas, ore, and petroleum are contributing to a host of environmental concerns. Possible solutions to these issues include the use of renewable energy sources that are less harmful to the environment and last longer.

Green electricity is becoming more important as the urban population continues to rise. Most rural communities still use traditional energy sources since renewable energy is still not widely recognised or known about. Renewable energy sources are more common and widely used in metropolitan areas, both for production and consumption. Thus, urbanisation is directly responsible for the increase of renewable energy sources. Urbanites are more likely to be environmentally conscious and to utilise renewable energy sources, according to studies conducted by Wirsbinna and Grega and Armeanu *et al*. (2021b). Consequently, the production of renewable energy is on the rise. The growth of urbanization-related industrial and transportation activity is the direct driver of the escalating energy consumption. Zeeshan *et al*. (2022) and found that renewable energy sources could meet large energy needs.

Renewable energy output is amplified by an increase in foreign direct investment. According to Wall *et al*. (2019), renewable energy production is enhanced when a country attracts a large influx of foreign investors who fund diverse economic sectors. This helps to fulfil the increasing need for energy. Rising FDI and technical advancement are two factors that are contributing to industrialization's uptick in renewable energy production (Przychodzen, Przychodzen, 2020, p.50). According to Wang *et al*. (2020), compared to agricultural sectors, industrial operations use a greater number of plants, equipment, infrastructure, and other forms of technology. Consequently, the conversion of agricultural units into manufactured commodities increases the need for energy; however, this demand might be satisfied by using renewable energy sources. Kristiansen *et al*. (2019) and Westerlund & Edgerton (2008) both find that technological advancements in the economy happen in tandem with the expansion of industrialisation, which is in line with our results. Broad acceptance of energy-efficient technology encourages both the use and generation of renewable energy sources.

5. Implications

In this study, the literature has shown to be valuable. The primary emphasis of this study has been on the energy production from sustainable sources. This study takes a look at the relationships between

industrialisation, GDP, exports, energy production, urbanisation, FDI, and the ASEAN region in order to fill a knowledge gap in environmental sustainability. The reliance on non-renewable energy sources, such fossil fuels, has led to a worsening of environmental challenges and a scarcity of resources. There is also a lack of certainty over the future of the economy. More exports, quicker GDP growth, and encouraging foreign investment in renewable energy are some of the many objectives that this study aims to help policymakers achieve. Regulatory authorities may use the suggestions given in this article to streamline rules concerning renewable energy technology usage. The report states that encouraging industry, urbanisation, and the use of renewable energy sources is necessary to increase the output of renewable energy. It would be wise for the governments of the sample countries to establish connections with wealthy nations, particularly those with sophisticated technology capabilities and creative industries. By putting greater faith in renewable energy sources close to home, they may broaden their perspectives. To ensure a seamless transition, these nations must vigorously support eco-friendly innovation and adopt green programs. The empirical findings of the study are significant for management authorities, as they are the ones who can provide support for the government to design effective and conducive economic and foreign investment policies that improve the environmental situation. These policies and procedures should not only promise rapid economic growth but ensure sustainability in the host country. Economic policy reforms need to be incorporated into foreign capital inflows which work towards environmental goals. This helps corporations maintain their profits and their socio-environmental impacts. Moreover, FDI should be enhanced in such a way that economies can thoroughly explore foreign investors' profiles and qualifications to stimulate environmental quality via advanced technologies brought by multinational firms in a harmonized manner (Kecek *et al*., 2019; Mendonca *et al*., 2020). Thus, Asian economies are advised to outline prudent policies for FDI flows while making the environment green and cleaner. It is recommended that, at the initial level, developing economies focus on socio-economic development by creating awareness, then switch to environmental protection, as it becomes easier to fulfil these goals when citizens have developed green behaviour.

Since current laws and policies are incompetent and rigid in terms of sustainable technologies in emerging nations. Thereby, government institutions are advised to develop strategies for showing support toward technology innovation. Such kind of strategies must be formulated to amplify the benefits and minimize costs by assessing sustainable technologies and encouraging development. Inefficient governance enforces cost on economies and communities. Hence, suppress benefits and act as a plague for environment and growth. Emerging nations show more sensitivity towards environment compared to developed nations due to technology lacking, poor governance, low investments, weak financial resources. Thereby, such economies utilize strategies that demoralize pollution and upgrade growth levels. Additionally, energy is a fundamental cause of pollution as most economies utilize nonrenewable resources for production and consumption reasons. Government must also assess the reliability of inexpensive and cleaned energy resources and make subtle investment in energy-saving technologies. Besides, economies should also re-evaluate the operational performance of existing environmental policies and make further advancement in R & D area. There is also a need of government intervention to create technology awareness and reduce environmental pollution. This is because without external force, technology adoption is not possible because it builds additional cost to execute policy. Therefore, it is imperative to make intervention for the support of sustainable technology promotion that would lead toward green future. An outstanding and endless effort is required to promote technological innovation and fight with pollution.

Industrialization is also vital to accumulate pollution. Industries with different scope and resources take different measures to embrace green technology. Thus, such regulations must be dynamic, flexible and elastic in nature in order to fit with economic and social structure. Environmental policies must be upgraded timely to make fruitful effect on environmental technologies. Government and institutions should also emphasize on FDI quality over quantity via green bonds in order to make economy competitive and environment protected. In reference to industrial structure, FDI appears to stimulate positive spill over impact on high technology sector, thus, industries must transform their existing parameters and expand their capacity in order to absorb technology. Besides, industries such expand their R&D area in order to bridge the technological gap among nations. Therefore, such policy should be formulated which improves FDI quality and enhance the capacity to acknowledge porter and pollution halo hypotheses.

Conclusions

According to the research, there is a positive relationship between renewable energy production, industrialisation, GDP, energy consumption, urbanisation, and foreign direct investment. Rising energy consumption, GDP, production, employment, and technological improvement all lead to the generation of renewable energy, according to the research. Rising exports lead to rising GDP, living standards, and other economic metrics. This promotes the growth of renewable energy sources. Progress in industrialisation, technological advancement, and foreign direct investment all lead to an increase in the generation of renewable energy. The results show that renewable energy will be in high demand due to the growing awareness of the environmental advantages and the proliferation of metropolitan areas.

This study has some limitations for future researchers for searching the renewable energy production that has some improvements through suitable additions. This research has also examined the only economic outcome for sustainable additions, due to the economic outcomes for sustainable energy technologies such as exports, use of energy, FDI energy outcome and urbanization. The human capital, green investment and the energy efficiency are the factors that are being influenced by the renewable production in energy. The findings of the study are also linked with use of energy, GDP, FDI, urbanisation and industrialization and this evidence is based on Asian economies. The selected economies do not necessarily present valid results about the relationships among the factors which are generalizable across the world, so future studies should collect information from diverse areas to explore these concepts.

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EKONOMINIŲ REZULTATŲ POVEIKIS TVARIOSIOS ENERGETIKOS TECHNOLOGIJOMS DEŠIMTYJE DIDŽIAUSIŲ AZIJOS ŠALIŲ

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Santrauka. Kalbant apie tvaraus ekonomikos augimo palaikymą, Azijos šalių ekonomika susiduria su panašiomis problemomis kaip ir kitos išsivysčiusios ekonomikos šalys. Tačiau nepaisant statuso regionui tenka didelė anglies dioksido emisijos našta dėl pernelyg intensyvaus neatsinaujinančių išteklių naudojimo. Regionas gali išlaikyti savo aplinkosaugos statusą pereidamas prie atsinaujinančiųjų energijos šaltinių. Šiame tyrime nagrinėjamas atsinaujinančių energijos išteklių poveikis kelių Azijos šalių ekonomikai 2008–2020 m. laikotarpiu. Koreliacijai įvertinti pasitelkti kovariacinio padidinto Dickey-Fuller (CADF) ir skerspjūvio padidinto IPS (CIPS) testai kartu su nuolat atnaujinamais poslinkio pataisytais (CUP-BC) ir atnaujintais visiškai modifikuotais (CUP-FM) įverčiais. Remiantis duomenimis teigtina, kad yra palankus ryšys tarp atsinaujinančios energijos gamybos ir finansinio pelno. Atsižvelgiant į rezultatus, pasirinktų šalių politikos formuotojai turėtų įvertinti TUI ir BVP kaip svarbias tvarios technologijos priemones. Atsinaujinančios energijos technologijas gali kurti vyriausybinės agentūros bendradarbiaudamos su verslo sektoriumi ir informacinėmis ir ryšių technologijomis (IKT), kad sumažintų jų priklausomybę nuo potencialiai pavojingų išteklių.

Reikšminiai žodžiai: tvarios energijos technologijos; eksportas; energijos vartojimas; urbanizacija; tiesioginės užsienio investicijos; industrializacija; atsinaujinančioji energija; dešimt didžiausių Azijos šalių.

Appendixes

Appendix 1

Table A. Measurements of variables

S#	Variable	Measurement	Source
01	Renewable Energy Production (REP)	Renewable electricity output	WDI
02	Gross Domestic Product (GDPG)	GDP growth %	WDI
03	Exports (EXP)	Exports in terms of GDP %	WDI
04	Energy Use (EU)	Energy use (kg of oil equivalent per capita)	WDI
05	Urbanization (URB)	Urban population	WDI
06	Foreign Direct Investment (FDI)	FDI net inflows in terms of GDP %	WDI
07	Industrialization (IND)	Industry value added	WDI