Renewable Energy 177 (2021) 1408–1420

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Renewable and non-renewable energy policy simulations for abating emissions in a complex economy: Evidence from the novel dynamic ARDL

Festus Fatai Adedoyin [a], Ilhan Ozturk [b, c, d, *], Festus Victor Bekun [e], Phillips O. Agboola [f], Mary Oluwatoyin Agboola [g]

[a] Department of Computing and Informatics, Bournemouth University, UK
[b] Faculty of Economics and Administrative Sciences, Cag University, Mersin, Turkey
[c] Department of Medical Research, China Medical University Hospital, China Medical University, Taichung, Taiwan
[d] Department of Finance, Asia University, 500, Lioufeng Rd., Wufeng, Taichung, 41354, Taiwan
[e] Faculty of Economics Administrative and Social Sciences, Istanbul Gelisim University, Turkey
[f] Mechanical Engineering Department, College of Applied Engineering, King Saud University (Al Muzahimiyah Branch), Riyadh, Saudi Arabia
[g] College of Business, Dar Al Uloom University, 1MizanSt. Al Falah, Riyadh, 13314, Saudi Arabia

ARTICLE INFO

Article history:
Received 16 February 2021
Received in revised form
26 April 2021
Accepted 4 June 2021
Available online 12 June 2021

Keywords:
Economic complexities
CO2 emissions
Novel dynamic ARDL
Renewable energy
Coal energy
Japan

ABSTRACT

According to the Economic Complexity Index, Japan was the number 1 most complex economy in the world. In addition to complexity, Japan pledges to reduce emissions by boosting cleaner energy sources. This study simulates two policies to highlight a path for Japan in achieving this ambitious energy and environmental target. The novel dynamic autoregressive distribution lag (ARDL) model and Kernel-based regularized least squares (KRLS) are adopted over panel data from 1970 to 2018. Empirical evidence from the ARDL and dynamic ARDL models shows that CO2 emissions have a significant long-term relationship with GDP per capita, renewable energy, and economic complexity index while air transport is significant in the short run. Putting it more elaborately, a unit increase in GDP per capita increase the emission by 0.84%–0.96% in the long run and 0.46%–0.48% in the short run. As regards renewable energy, a unit increase in it decrease the carbon emission by 0.07% and 0.04% in the long-run and short-run respectively. Also, an increase in the economic index diminished the emission by 0.81% in the long run. Moreover, economic complexity moderates the role of GDP in environmental degradation as it also has a significant impact on carbon emission.

1. Introduction

According to The Intergovernmental Panel on Climate Change [1], “Anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented in at least the last 800,000 years. Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed warming since the mid-20th century.” This emissions, which are the root cause of environmental degradation, are diverse gaseous compound that is equipped for retaining or exuding infrared radiation, accordingly, catching warmth in the air [2]. Furthermore, according to the Environmental Protection Agency [3]; carbon dioxide (CO_2), methane (CH_4), Nitrous oxide (N_2O), ozone (O_3), and water vapour (H_2O) are the primary greenhouse gases in the earth's atmosphere with CO_2 contributing to about 76%, thereby affecting the atmospheric pressure and consequently upsetting the standard of living of many countries.

Dogan et al. [4] posited that the toxic environmental hazard that nations have ever experienced is from global warming, which is mainly related to environmental degradation from CO_2 emission.

* Corresponding author. Faculty of Economics and Administrative Sciences, Cag University, Mersin, Turkey.
E-mail addresses: fadedoyin@bournemouth.ac.uk (F.F. Adedoyin), ilhanozturk@cag.edu.tr (I. Ozturk), fbekun@gelisim.edu.tr (F.V. Bekun), pagboola@ksu.edu.sa (P.O. Agboola), maryagboola@dau.edu.sa (M.O. Agboola).

https://doi.org/10.1016/j.renene.2021.06.018
0960-1481/

Primarily, according to United Nation Environmental Protection Agency [5]; the sources of anthropogenic emission (CO_2) result from fossil fuel combustion which comes from electricity and heat, petroleum and natural gas, manufacturing, agriculture, forestry, deforestation as well as energy consumption, which is the key source of emissions. This is because the 2.4% increased in demand of average use of energy between the eighth century and twentieth century as researched by Javis et al. [6] continuously increase the environment which emanates from an impact of energy consumption as studied by Can and Gozgor [7].

Various scholars have examined the nexus between environmental emission, energy consumption (renewable and nonrenewable), GDP per capita, air transport, urbanization technology, coal rent, and energy investment. Because the economic growth of a nation greatly influences emission [4], the rationale behind their studies suggests a realistic step for policy directions to dwindle environmental degradation while maintaining a balance between energy consumption for proper sustainability growth [8]. However, despite the status of the economic structure of countries on the environmental consequence, few scholars consider the role of the economic complexity index (ECI) in such countries.

Economic complexity, as posited by Hidalgo [9]; is the capabilities of nations regarding products and manufacturing procedures. High estimation of economic complexity means how refined the nations' products are [10]. The level of economic complexity shows the nations' capacities as well as exhibits the variety of the production of merchandise and ventures. Also, it gives a comprehensive perspective on the scale, structure, and technological changes of a nation [4]. It is an outflow of a nation's imaginative yield which depends on research and development activities in the economy to create more advanced and complex products that promote less polluting modern technologies in energy utilization's efficiency and lessening climatic problem [11]. As an exact indicator of income per capita, economic complexity might be utilized as a logical variable, as demonstrated by Can and Gozgor [7] which revealed that economic complexity is an important indicator for stifling the degree of carbon discharges in France.

Carbon dioxide discharges, principally from the burning of petroleum derivatives, have risen significantly since the beginning of the modern revolution. The greater part of the world's ozone-depleting substance emission come from a moderately small number of countries, especially the three greatest emitters, such as China, the US, and the countries that make up the European Union. Per capita, GHG emanations are most noteworthy in the US and Russia. As seen from Fig. 1, carbon emission has significantly increased since 1995 before it dropped in 2010, then a manifold increase until 2014 where it begins to drop again. Also, GDP per capita rose from 1995 to 2020 indicating that the world economy has consistently improved. Moreover, there is an upsurge in the use of energy while ECI has been on decreased until about 2014 where it increased before decreasing again.

Still, on the figure, coal rents varied year by year, it has the highest energy consumed between 2005 and 2010 and declined till about 2019. Regarding the yearly passenger carried through means of air transport, and increased from 1995 till 2020 was observed, this illustrates air transport generates more impact on global economic growth.

Communities around the continents are desperately in need of important transformation to the utilization of energy production. This will allow the world to utilize more cleaner, renewable form of energy than excessive burning of fossil fuels. This quick arrangement of renewable energy has been driven fundamentally by a wide scope of drivers, which are reduction in GHG emission, improvement in economic growth, energy security, energy access and alleviating environmental change. According to Rüstemoglu & Andrés [12]; the foremost factors, of all anthropogenic emission, to achieve proper sustainability for renewable energy is a reduction in CO_2 emission. The same outcome is also achieved by Marques et al. [13]; Aguirre & Ibikunle [14]; Rafiq et al. [15] and Salahuddin et al. [16]. The four studies agreed to the view that CO_2 emission is the key indicator that fostering renewable energy deployment. Another important indicator is energy consumption which denotes the energy use of a nation. Sources of energy consumption could be from nonrenewable sources, renewable sources, or a combination of both [13]. As reported by International Energy Agency [17], an increase in population and economic growth of a country is expected to increase energy demand in the future years. This means that there is a substantial need to allow the current generation to enjoy modern energy and also devise strategies to house energy for upcoming ones. Base on this, a viable option for satisfying the rising energy demand, for nations with huge country growth rate, is the deployment of renewable energy [18].

Moreover, deployment of renewable energy could also result from GDP or GDP per capita which measured the economic growth of a country. For example, the major indicator of renewable energy is an increased in real GDP per capita [19] indicating that as the wealth of a nation becomes higher, renewable energy consumption is required. The same result was acquired by Apergis & Payne [20]; Menegaki [21]; Ohler & Fetters [22]; Dogan and Ozturk [23]; and Ozcan and Ozturk [24].

Base on the above excerpt, it is noteworthy that an important factor to determine the needs of a national sustainability development is renewable energy deployment. Thus, it should be given high priority, hence the rationale behind this study which is to examine, using Japan as a case study, the role of renewable energy and non-renewable for abating emission in a complex economy. The reason for choosing Japan is not far fetched. Firstly, according to the World Resource Institute, one of the most 10 emitters of greenhouse gas emission is Japan contributing to about 2.73% of total global emission. Also, in 2013, Japan GHG emits more than 1 billion tons, but after that, the quantity of emission had been on declined till 2018. By 2030, a 26% decrement in GHG compared to 2013 is expected. Of all country in the world, Japan is known to have the highest ECI value of 2.43 index, and known as the second most advanced economic country in the world, and the third-largest by nominal GDP. As such, this study contributes to the existing literature by introducing economic complexities in the energy consumption-emissions debate alongside other vital variables such as air transport, GDP per capita, and energy use to determine the environmental consequence or degradation in Japan. ECI is the main predictor variable – to contribute to the 2030 plan and communicate the results to the policymakers and other concerned authorities. Thus, policy simulations are carried out using a more recent and advanced dynamic ARDL simulation approach. The next section presents a review of the literature on economic complexities as well as other control variables and their connection in emitting CO2. Section three presents the data used, description of variables and the model adopted for the study. Pre and post estimation checks and estimation of main models are presented in section four, while section five carries out policy simulations. The study concludes in section six with vital policy implications and recommendations.

2. Literature review

2.1. Economic complexity index and environment nexus

Within the context of environmental literature, various researchers have considered the nexus between environmental degradation and numerous factors variables (economic growth, air

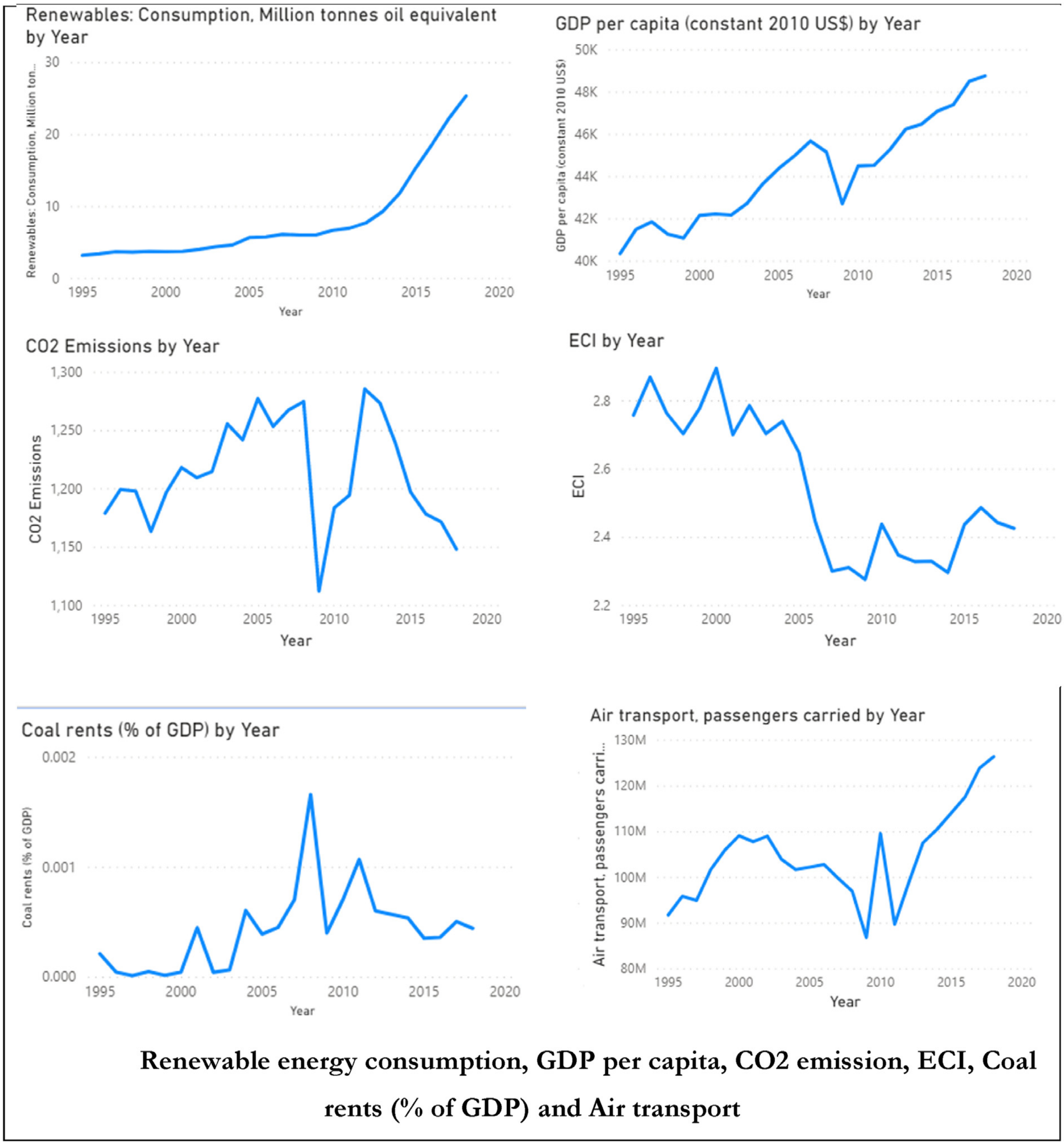


Fig. 1. Renewable energy consumption, GDP per capita, CO2 emission, ECI, Coal rents (% of GDP) and Air transport.

transport, renewable and nonrenewable energy consumption, social, technological, environmental, and institutional) as predictors variables. This current paper presents a new predicator variable in the examination of the determinants of environmental problem, specifically, the economic complexity index (ECI). Thus, related research on the complexity of the economy, and environment are talked about beneath. Hidalgo (2019) the capabilities and qualifications of countries in terms of products, technology and manufacturing developments of nations is the reflection of complexity. The high value of economic complexity is a signal of how highly sophisticated countries' financial growth structure are [10]. The level of economic complexity shows the countries' capacities as well as exhibits the variety of the creation of merchandise and ventures.

Also, it gives an all-encompassing perspective on the scale, structure, and technological changes of a nation [4]. Economics complexity is identified with a nation's degree of success and there is a fitted relationship between economic complexity and Gross domestic product per capita. Also, nations will, in general, move towards a profit level that is viable with their general degree of productive knowledge, implying that their profit tends to mirror their entrenched knowledge [25]. Various scholars have reached a similar conclusion in their research that economic complexity is a parameter that contributes to economic growth [26].

The ECI, according to the Center for International Development at Harvard University, is an expression of the multiplicity and intricacy of a country's exportation basket [25]. The index is determined for 128 countries, based on information from UN

COMTRADE, the International Monetary Fund and World Development Indicators. The improved abilities of a country in a production process is demonstrated by high estimates of ECI [10]. The cycle of monetary advancement could be clarified as a cycle of figuring out the steps in the productions and exportation of more multifaceted products [27].

From an overall perspective, economic complexity alludes to a nation's productive structure, which prompts a particular structure of energy use and, as result, a particular impact on the climate. A nation's productive structure could impact GHG emanations while the complexity level of products could harm the environment by emitting pollution, however, it also entrenches knowledge and capabilities, innovations and research, which can assist with invigorating greener products and friendly advancement in the environment. The two significant parameters affecting the quality of the environment are countries' composition of products and level of technology [28]. The main factor in reducing environmental degradation, according to Kaufmann et al. [29]; is the structure of products of the country. At a time when there are less sophisticated products, the country's environment may be detrimental. Thus, it is expected environmental performance is significantly affected by economic complexity. As a precise indicator of GDP per capita, the product structure of a country (ECI) may be used as a significant predictor. However, few studies have connected the ECI to environmental consequence.

An example of the first study, to examine the ECI on environmental degradation, is developed by Can and Gozgor [7] which revealed that the economic complexity is a vital indicator for lessening the CO_2 emission in France. In a more extensive study of 25 Union of European nations, the economic complexity exerts an inverted-U shaped effect on GHG emission. This showed that as economic complexity increases, the carbon emission increases, but after the emission level reached a certain point, it begins to decline while the economic structure (product and advanced technology) continuing to increase. Thus, economic complexity decreases the emission level [11].

Another study of economic complexity on environmental degradation a study carried out by Buhari et al. where he examined the effects of ECI on CO_2 emission on three various income groups. The analysis revealed that the ECI have a substantial influence on the environment. The carbon emission in high-income countries was controlled by ECI, whereas in the higher middle-income and lower-middle-income countries, the ECI increased the carbon emission.

2.2. Energy use, air transport and the environment

Energy resources are commonly seen to be one of the significant components of world energy consumption, and major financial growth and development in numerous manufacturing economies. However, the constant misuse of energy assets by man is putting the natural climate under dynamic pressure. Thus, there have been a few instances of environmental obstructions, for example, ecological contamination, environmental degradation, and global warming, and a mass of other predicaments that threatening the existence of the public as well as financial development and advancement of the worldwide economy [30]. In this regard, fatal illness, as well as humans' death, has been largely caused by the pollutant emission from non-renewable energy sources such as coal, firewood, fossils, and fuel [31]. [11] posited that the energy sector in both developed and emerging countries is one of the most primary sources of pollutant emission. This has caught the attention of various researchers, hence various studies which analyzed the effects of energy use in the developed and the developing countries across the continents.

For instance, Sharif et al. [32] examine the energy consumption-carbon emission nexus. The result confirmed that non-renewable energy use has a positive impact on emission while renewable energy use harms carbon emission, and thus assist in reducing the environmental hazards caused by environmental degradation. On the contrary, there is a strand of literature that revealed that renewable energy does not influence the decrease in carbon emission [52]. To support this view, the bidirectional link between environmental emission and renewable energy consumption, nuclear energy consumption, and economic growth was examined by Apergis et al. [33]. The result of the examination shows that, in the long run, carbon emission is significant to be influenced by green energy consumption, whereas the opposite is the case for renewable energy consumption in the short run. This means that renewable energy does not contribute to the lessening of carbon emission. Along with this is a study in Malaysia where a unidirectional causal link between energy consumption and carbon emission, in the long run, has been established [34].

On the other hand, the energy use-emission nexus in G7 countries was investigated by Ajmi et al. [35]. The findings of causality between the studied variables suggested the bidirectional time-varying causality runs for the case of the USA, whereas for France, unidirectional causality was established in the sense that the direction of causality only runs from energy use to carbon emission meaning that energy consumption caused a reduction in CO_2 emission. No causality difference is established for other G7 countries including Japan. Also, the verification of the causal relationship between energy use and emission of carbon was established in Vietnam [36]. The result of the causality revealed the indication of one-directional indicating that the direction of connection runs from energy to emission.

Another noteworthy study is the investigation of the nexus between energy use, nuclear energy and carbon emission in the USA where there is an indication that renewable energy consumption has not yet reached a stage where it could have a resounding impact on the reduction of CO_2 emission [37]. In the same country, another study was carried out by Soytas et al. [38]. But the outcome is not in tandem with that of the previously cited literature in the sense that the granger causality revealed the unidirectional link that runs from energy use to CO_2 emission. The productivity of energy use can be improved through mechanical advancement as Miao et al. [39,40] featured on account of strategic developing enterprises in China [39,40].

Regarding air transport-environment nexus, the impact of transport on the environment is important because the transport system is the main user, and it consumes the greater part of the world's oil. This leads to air pollution, as well as NO_2 (nitrous oxides) and particulates, and it (transport system) is a significant indicator of global warming through the emanation of (CO_2) carbon dioxide [41]. There are many means of the transport system, but air transport will be the major concentration in this study. Like practically every area of human action, air transport has an impact on the climate environment. The several forms taken by the air transport impact on climate environment includes but not limited to the disturbance caused by aircraft noise and aircraft engine emissions.

Air travel overwhelms a regular tourist's commitment to environmental change. However, aviation by and large records for just 2.5% of worldwide carbon dioxide (emanation of 1.04 billion tonnes of CO_2 emanation in 2018) [42]. This is because there are enormous disparities in how much individuals fly (many do not or incapacitated to). Lee and colleagues [42] stretched out the more facts about air travel not only emitting CO_2 but additionally influence the concentration of different gases and pollutant in the climate which bring about a decline in ozone and methane, emission of water

Table 1
Description and Summary Statistics of variables.

Variables	Data source	Mean	Std. Dev.	Min	Max
Co2 Emissions (metric tonnes per capita)	British petroleum	6.985	0.134	6.698	7.159
Per capita GDP (constant 2010 $ price)	World Bank Database	10.462	0.291	9.836	10.795
Renewable energy consumption (Million tonnes oil equivalent)	British petroleum	0.646	1.787	−2.932	3.234
Air transport (passengers carried)	World Bank Database	18.020	0.559	16.608	18.655
Coal rents (% of GDP)	World Bank Database	−6.737	2.404	−11.076	−2.872
Economic complexity index	ATLAS of Economic Complexity (2020)	1.925	0.857	0.001	2.895
Interaction term	Authors computation	20.375	9.280	0.011	30.831

vapour. Hence, the general effects of aviation on global warming were evaluated to represent 3.5% of warming [42]. Based on these facts, some scholars have researched the air transport-emission nexus. For example, related annual harms of global air travel are likely more than one billion dollars for noise and up multiples times as enormous as environmental change. No arrangement adequately addresses noise, air quality and environmental change impacts. Moreover, the foreseen development of air transportation request will very likely consume decreases, in any event throughout the following 20 years [43]. According to other evaluations, the airline travel sector is estimated to be 3.5% of anthropogenic global GHG emissions [44]. In the European Association, it is assessed that the air transport sector releases about 4% of the complete EU carbon emanations [45]. The European Environmental Agency (EEA) says that carbon emanations in the EU from international airline expanded by 96% in the period 1990–2005 [3].

There is a limited number of studies that assess the association between environmental ECI and predictor variables such as air transport, energy consumption, GDP, and coal rents on an environmental consequence in the form of carbon emission. In this regard, the review of related studies is limited and constitute a fairly different result. Even to the author's knowledge, no published paper has ever linked the significant impact of air transport on environmental degradation. Although some scholars have investigated the effects of air transport on economic growth [46]. Thus, this fresh study is demanded to clarify the empirical results from the existing literature and as well as establishing a new study on the effect of the air transport system. This fresh study incorporates the ECI along with air transport, energy use on environmental incidence taken Japan as a case study. The reason for ECI is because it has attracted important attention from various researchers and policymakers. It also explained variation in national economic growth and per capita income [25].

3. Data and methods

3.1. Data and variables

Table 1 shows the variables' description and the descriptive statistics of the original data. The mean average, in metric tonnes, of CO2 emission is 6.985 which is between 6.698 and 7.159 with a standard deviation of 0.134 which shows that there is less dispersion between the actual data and its mean. The mean value of per capita GDP is $10.462 with a dispersion of $0.291 and ranges between $9.836 and $10.795 indicating less variability from the sample mean. Similarly, on average, the mean of renewable energy consumption in million tonnes is 0.646 which ranges between the maximum and minimum value of −2.932 and 3.234 with a variability score of 1.787. The average of passengers transported throughout this period is approximately 18 passengers which ranges between approximately 17 and 19 passengers with a standard deviation of 0.6 indicating that passengers carried are not much dispersed from its mean. On average, coal rents (% of GDP) has a mean value of −6.737%, variability scores of 2.404% showing a large deviation from its mean. It also has a minimum and maximum of −11.076% and −2.872% respectively. On average, the economic complexity index has a mean of 1.925; has a deviation of 0.857; and ranges between 0.001 and 2.895. Finally, the average value of the computed interaction term is 20.375 which falls between 0.011 and 30.831 with a standard deviation of 9.280 which indicates that there is a wide disparity between the author's observation of the interaction term and its mean.

3.2. Model and methods

A carbon emissions function is adopted for this study. This is specified as:

$$CO2 = f(RGDP,\ RNW,\ COR,\ ATP,\ ECI)$$

The dynamic ARDL simulation is based on the 2018 estimate from Carbon Brief (2018) for Japan's target to reduce emissions by 26%. This target is used as a counterfactual shock over 20 years from 2018 to 2038. The model specification of the proposed dynamic ARDL simulations can be expressed as

$$\begin{aligned}\ln(CO2)_t = {} & \beta_0\ln(CO2)_{t-2} + \beta_1\ln(RNW)_t + \beta_3\ln(RNW)_{t-2} \\ & + \beta_4\ln(RGDP)_t + \beta_5\ln(RGDP)_{t-2} + \beta_6\ln(COR)_t + \beta_7\ln(COR)_{t-2} \\ & + \beta_8\ln(ATP)_t + \beta_9\ln(ATP)_{t-2} + \beta_{10}\mathrm{ECI}_t + \beta_{11}ECI_{t-2} \\ & + \beta_{12}\ln(RGDPECI)_t + \beta_{13}\ln(RGDPECI)_{t-2} + \varepsilon_t\end{aligned}$$

where CO2 represents Carbon emissions; RGDP represents Real GDP per capita; RNW represents renewable energy consumption; ATP represents Air Transport; COR represents Coal Rents; ECI represents Economic Complex ε is the error time in time t.

The chart in Fig. 2 revealed the procedure followed in carrying out the empirical study which is in line with Sarkodie and Owusu [47]. To avoid the spurious result of the ARDL model, it is recommended to test the stationarity (constant mean and variance of series) of the variables. This will be done using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root test. ADF and PP test is a hypothesis of the unit root (non-stationarity) in the null hypothesis. If the null hypothesis is rejected at the first level, then the series is stationary, otherwise, it is nonstationary and needs differencing to make it stationary. The stationarity test can be a subject autoregressive distributed lag model (ARDL), and finally to dynamic ARDL (DYNARDL) estimation.

4. Results and discussion

The unit root test of the log of variables is tested and presented in Table 2. At the level of the PP test, CO2, RNW, and COR are non-stationary. Also, at the level of ADF, four variables which are CO2, RGDP, RNW, and COR are non-stationary since their absolute t-value is less than a critical value. However, after the first difference

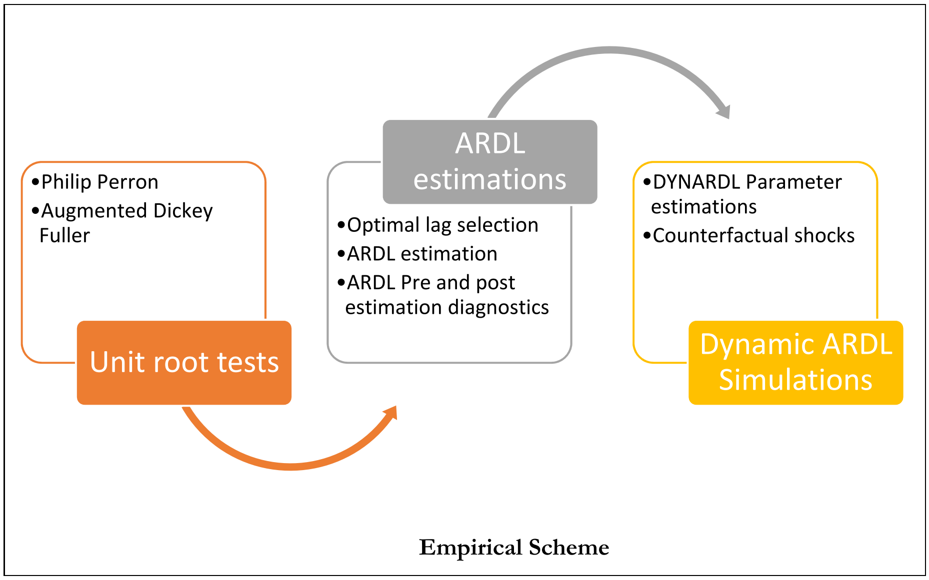


Fig. 2. Empirical scheme.

Table 2
Stationary test.

Variable	Level. PP	Δ. PP	Level.ADF	Δ. ADF
lnCO2	−4.268	−7.213***	−2.174	−7.133***
lnRGDP	−1.911**	−4.813***	−3.798	−4.837***
lnRNW	−1.794	−6.550***	−1.410	−6.551***
lnCOR	−4.256	−7.699***	−1.735	−7.473***
lnATP	−3.012***	−6.978***	−3.688**	−6.955***
ECI	−2.829*	−4.503***	−4.109***	−4.439***
lnRGDPECI	−2.675*	−4.657***	−3.887**	−4.568***

Level.PP is the level of PP unit root, Δ. PP is the first-difference value; Level.ADF level of ADF, Δ.ADF is the first difference; ***, **, * significance at 10%, 5%, and 1% respectively.

of PP and ADF unit root test, the null hypothesis of non-stationarity is rejected thus confirming that the data series are of the difference of order one I (1). Therefore, the ARDL model can be evaluated using the integrated variables. Furthermore, after satisfying the condition of stationary series, the next is to determine the number optimal lag for estimation of the ARDL model. The resulting estimated parameters based on the lag ARDL (1,0,0,1,0,1) is presented in Fig. 3 with its empirical results presented in Table 3. The long-run and short-run estimation involved two models which are the model without the computed interaction term and the full model.

4.1. ARDL model estimation

The result of the analysis in Table 3 reveals that real GDP per capita and renewable energy are found to be significant predictors of CO2 emission in both short-run and long-run analysis whereas the air transport system is only significant in the short run. Variables such as coal rent and economic complexity index are not significant in both the short-run and long run. Furthermore, the r-squared value of 0.630 implies that 63% of the variability in the CO2 emission can be accounted for by the explanatory variables. When the interaction term is considered, the result of the full model indicates that real GDP per capita, renewable energy, and the interaction term (i.e., real GDP per capita and economic complexity) are found to be significant in both short-run and long-run analysis whereas ECI and air transport system are significant only in the long run and short run respectively. Variables such as coal rent, CO2 emission are not significant in both the short-run and long run. Furthermore, the r-squared value of 0.621 implies that 62.1% of the variation in the CO2 mission can be explained by the explanatory variables.

Table 3
ARDL (1,0,0,1,0,1) regression.

Variables	Model without an Interaction term	Full Model
ECT	−0.497***	−0.541***
	(0.107)	(0.124)
Long-Run		
$lnRGDP_{t-1}$	0.957***	0.845***
	(0.210)	(0.208)
$lnRNW_{t-1}$	−0.0695***	−0.0733***
	(0.0132)	(0.0125)
$lnATP_{t-1}$	−0.172	−0.105
	(0.124)	(0.123)
$lnCOR_{t-1}$	0.00123	0.00457
	(0.00850)	(0.00819)
ECI_{t-1}	0.0656	−0.810*
	(0.0491)	(0.433)
$lnRGDPECI_{t-1}$		0.0822**
		(0.0403)
Short-Run		
Δ lnRGDP	0.476***	0.457***
	(0.101)	(0.101)
Δ lnRNW	−0.0346***	−0.0396***
	(0.00821)	(0.00989)
Δ lnATP	0.177**	0.135*
	(0.0760)	(0.0738)
Δ lnCOR	0.000610	0.00247
	(0.00422)	(0.00445)
Δ ECI	−0.0818	−0.438
	(0.0629)	(0.279)
Δ lnRGDPECI		0.0444*
		(0.0262)
Observations	48	48
R-squared	0.630	0.621

Notes: Standard errors in parentheses with ***$p < 0.01$, **$p < 0.05$, and * $p < 0.1$ represents statistical significance levels. **Legend**: CO2 represents Carbon emissions; RGDP represents Real GDP per capita; RMW represents renewable energy consumption; ATP represent Air Transport; COR represent Coal Rents; ECI represents Economic Complex.

Under this section, the long-run cointegration relationship

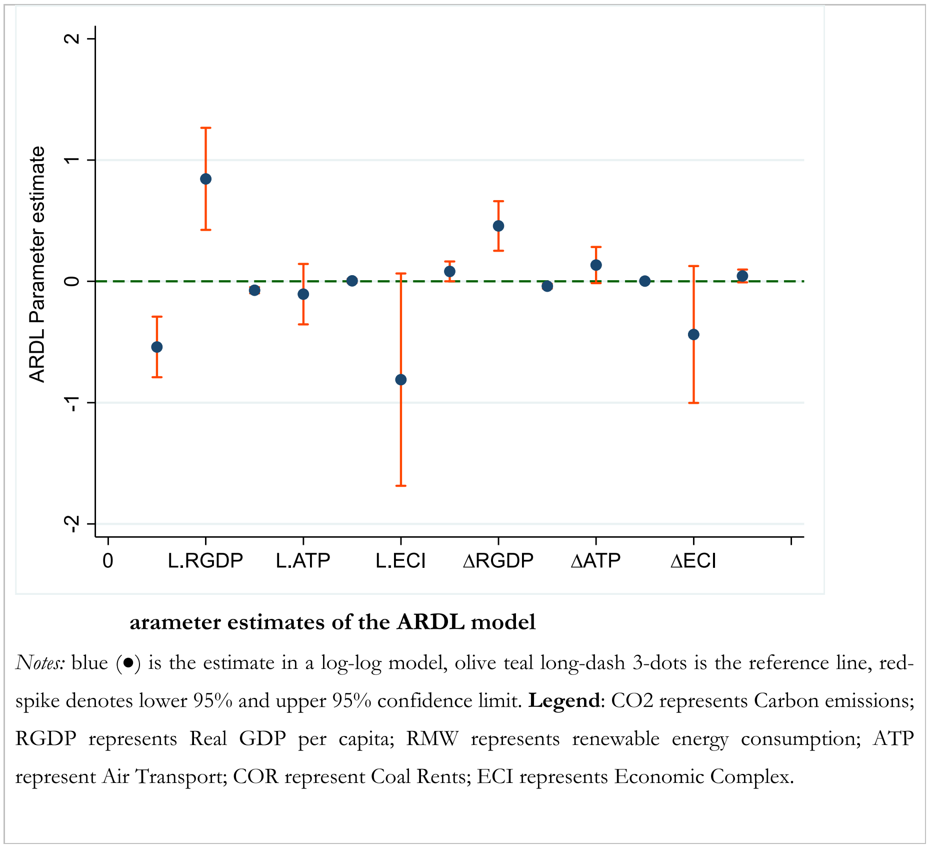


Fig. 3. Parameter estimates of the ARDL model. *Notes:* blue (●) is the estimate in a log-log model, olive teal long-dash 3-dots is the reference line, red-spike denotes lower 95% and upper 95% confidence limit. **Legend**: CO2 represents Carbon emissions; RGDP represents Real GDP per capita; RMW represents renewable energy consumption; ATP represent Air Transport; COR represent Coal Rents; ECI represents Economic Complex.

between short-run coefficient was examined using Pesaran, Shin, and Smith (PSS) bound test accompanied with Kripfganz & Schneider (KS) critical value. The result is presented in Table 4(a). From the table, the joint F-statistic of the explanatory variables (short-run coefficients) is 4.797 while the absolute value of t is −4.374 which is more than the upper bound, I (1), critical values

Table 4
Model diagnostics tests.

a. Pesaran, Shin, and Smith bounds testing

	K	10%		5%		1%		*p-value*	
		I (0)	I (1)	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
F	4.797	1.917	3.147	2.305	3.679	3.218	4.907	0.001**	0.012**
t	−4.374	−1.612	−3.687	−1.966	−4.096	−2.668	−4.907	0.000**	0.030**

b. Breusch-Godfrey LM test for autocorrelation

lags(p)	F	Df	Prob > F
1	0.134	(1, 40)	0.7161
2	0.153	(2, 39)	0.8589
3	0.162	(3, 38)	0.9216
4	0.195	(4, 37)	0.9393

c. **Cameron & Trivedi's decomposition of IM-test.**

Source	chi2	Df	*p-value*
Heteroskedasticity	21.14	27	0.7797
Skewness	6.99	6	0.3221
Kurtosis	0.67	1	0.4143
Total	28.79	34	0.7207

d. Skewness/Kurtosis tests for normality

Variable	Obs.	Pr. (skewness)	Pr. (kurtosis)	Joint adj. chi^2 (2)	Prob > chi2
Residuals	48	0.1547	0.8005	2.21	0.3318

I(0) is the lower band critical values; I(1) is the upper band critical values; ** indicate the significance of KS critical values at the 0.01 significance level.

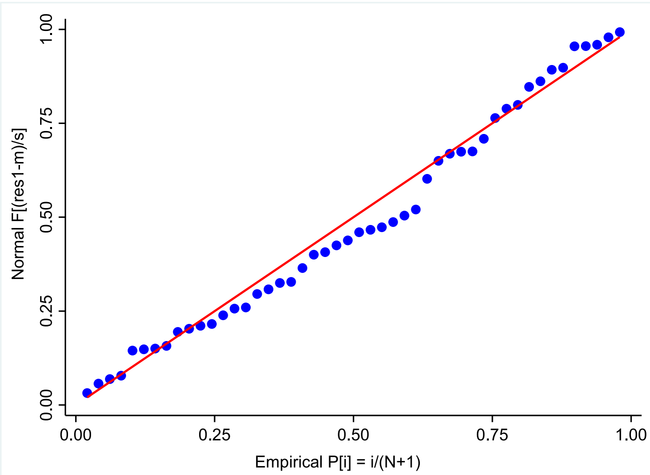


Fig. 4. Standardized normal probability plot.

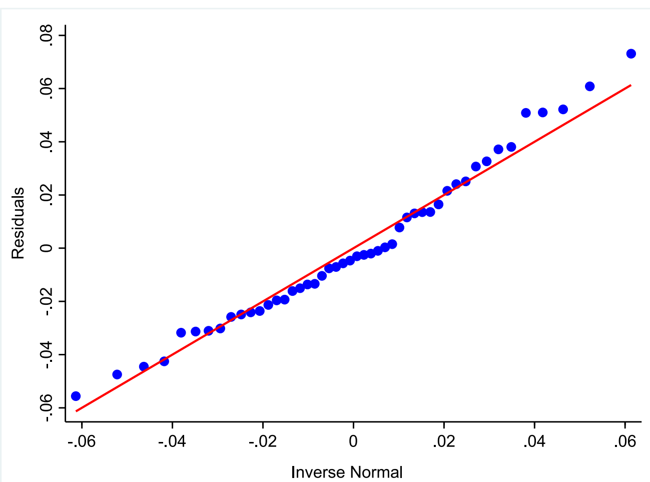


Fig. 5. Quantiles of residuals against quantiles of normal distribution.

at 10% and 5% significance level. The KS significant value (p-value < 0.01) further validate the result, hence leading to the rejection of no cointegration in H_0. Thus, the existence of long-run cointegration was confirmed by both tests.

As part of the assumption of the dynamic autoregressive lag model, various tests were performed to avoid serial correlation (the relationship between given variables and its lagged value), autocorrelation, heteroscedasticity, and violation of normality assumption, and structural break. Table 4(b) revealed the autocorrelation test using the Breusch-Godfrey LM test of serial correlation (presence of autocorrelation in the null hypothesis). It can be observed from the result that the hypothesis of no serial correlation between variables and its lagged value is rejected at a 5% level of significance (p-value>0.05), thus the residual of the estimated ARDL (1,0,0,1,0,1) are devoid of autocorrelation. Cameron & Trivedi's decomposition of the IM-test presented in Table 4(c) was used to examine if the residuals are heteroskedastic in nature. The p-value which is above 0.05 significance level denoted that the statement of homoscedasticity of H_0 fails to be rejected. Hence, the residuals are not heteroscedastic. Furthermore, the normality assumption of independence of residuals was examined using the skewness and kurtosis test. The result in Table 4(d) revealed that the statement that the residuals followed normal distribution in the H_0 fails to be rejected at the 0.05 significance level. Hence, the residuals are normally distributed within the mean.

4.2. ARDL regression: post-estimation diagnostics

The validation of normality assumption assessed by skewness/kurtosis test was further tested using standardized normal probability plot (Fig. 4) and quantiles of residuals against quantiles of normal distribution (Fig. 5). Both plots attest that the residuals based on ARDL (1,0,0,1,0,1) are normally distributed. Finally, the structural break was examined by the cumulative sum for the stability of the estimated parameters. The result as was presented in Fig. 6 shows that the test statistic of the estimated parameters is within a 95% confidence interval. Thus, the stability of the estimated coefficients of the parameters over time was confirmed.

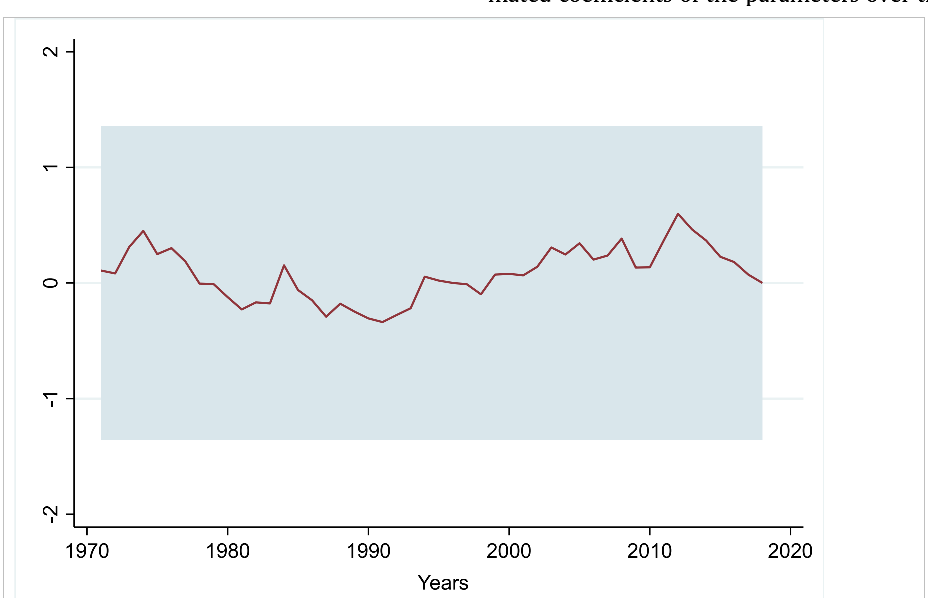
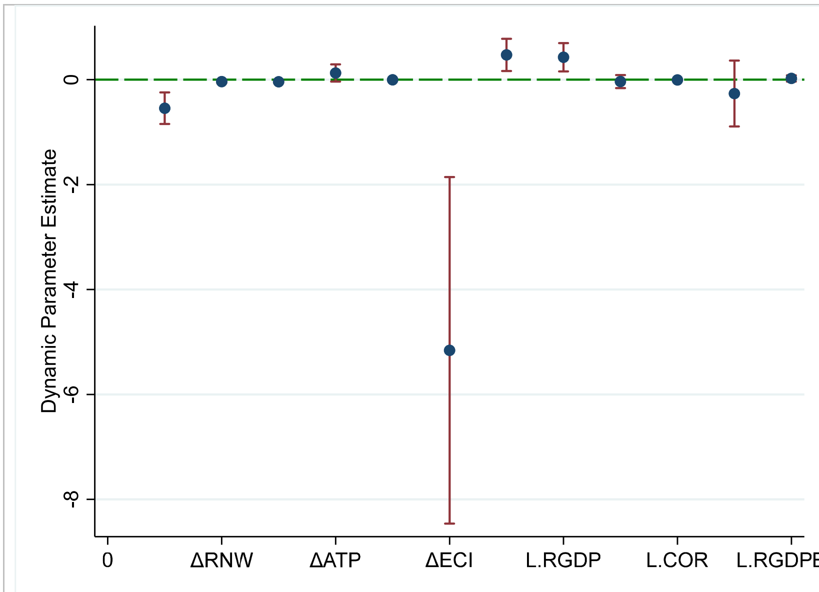


Fig. 6. Cumulative sum test using OLS CUSUM plot for parameter stability.



Parameter estimates of dynamic ARDL Simulations

Notes: black dot is the estimate in a log-log model, olive teal long- dash 3-dots is the reference line, red-spike denotes lower 95% and upper 95% confidence limit. **Legend**: CO2 represents Carbon emissions; RGDP represents Real GDP per capita; RMW represents renewable energy consumption; ATP represent Air Transport; COR represent Coal Rents; ECI represents Economic Complex.

Fig. 7. Parameter estimates of dynamic ARDL Simulations. Notes: black dot is the estimate in a log-log model, olive teal long-dash 3-dots is the reference line, red-spike denotes lower 95% and upper 95% confidence limit. **Legend**: CO2 represents Carbon emissions; RGDP represents Real GDP per capita; RMW represents renewable energy consumption; ATP represent Air Transport; COR represent Coal Rents; ECI represents Economic Complex.

5. Energy policy simulations

5.1. Dynamic ARDL simulations

Various studies have employed dynamic ARDL to capture future shocks in socioeconomic and climatic factors [48]. The simulation of dynamic ARDL is based on ~26% energy consumption for over 20 years (that is a period of 2018–2038). The parameter plot of the dynamic ARDL is presented in Fig. 7 while its empirical estimation is in Table 5.

The model without the interaction term as shown by the result of the analysis in Table 5 indicate that only renewable energy significantly predicts CO2 emission, in the long-run and short-run, that is, renewable energy in this context has a negative relationship with CO_2 emission. This output aligns with the study of Sharif et al. [32] which confirm that renewable energy has a significant inverse relationship with carbon emission, and thus assist in reducing the environmental hazards caused by environmental degradation. On the contrary, the energy-emission nexus investigation carried out by Apergis et al. [33] and Azlina and Mustapha [34] refute the outcome of this study by concluding that renewable energy does not reduce carbon emission. Also, the full model analysis result indicates that renewable energy negatively predicts CO2 emission in the long-run and short-run which conform with the literature referenced above. Furthermore, without the interaction term, air transport and real GDP per capita are significant in the short-run and long-run respectively, and the r-squared value of 0.570 implies that 57% of the variability in the CO2 emission can be accounted for by the explanatory variables. However, with the interaction term, real GDP per capita is still significant in the long run whereas both ECI and interaction term are significant in the short run. This indicates that the positive influence of the economic

Table 5
Estimates of dynamic simulated ARDL model.

Variables	Dynamic model without an interaction term	Full model
	dlnCO2	dlnCO2
$lnCO2_{t-2}$	−0.582***	−0.545***
	(0.142)	(0.148)
Δ lnRNW	−0.0350**	−0.0362**
	(0.0157)	(0.0147)
$lnRNW_{t-2}$	−0.0340***	−0.0392***
	(0.0112)	(0.0123)
Δ lnCOR	0.00394	−0.00212
	(0.00548)	(0.00551)
Δ lnATP	0.250***	0.128
	(0.0779)	(0.0812)
Δ ECI	−0.0831	−5.160***
	(0.0693)	(1.629)
Δ lnRGDPECI		0.473***
		(0.152)
$lnRGDP_{t-2}$	0.452***	0.428***
	(0.145)	(0.133)
$lnCOR_{t-2}$	−0.00224	−0.00437
	(0.00559)	(0.00567)
$lnATP_{t-2}$	−0.0376	−0.0357
	(0.0639)	(0.0615)
ECI_{t-2}	0.0107	−0.265
	(0.0296)	(0.309)
$lnRGDPECI_{t-2}$		0.0239
		(0.0294)
Observations	48	48
R-squared	0.576	0.666
Prob > F	0.0000***	

Standard errors in parentheses with ***p < 0.01, **p < 0.05, and * p < 0.1 represents statistical significance levels. **Legend**: CO2 represents Carbon emissions; RGDP represents Real GDP per capita; RMW represents renewable energy consumption; ATP represent Air Transport; COR represent Coal Rents; ECI represents Economic Complex.

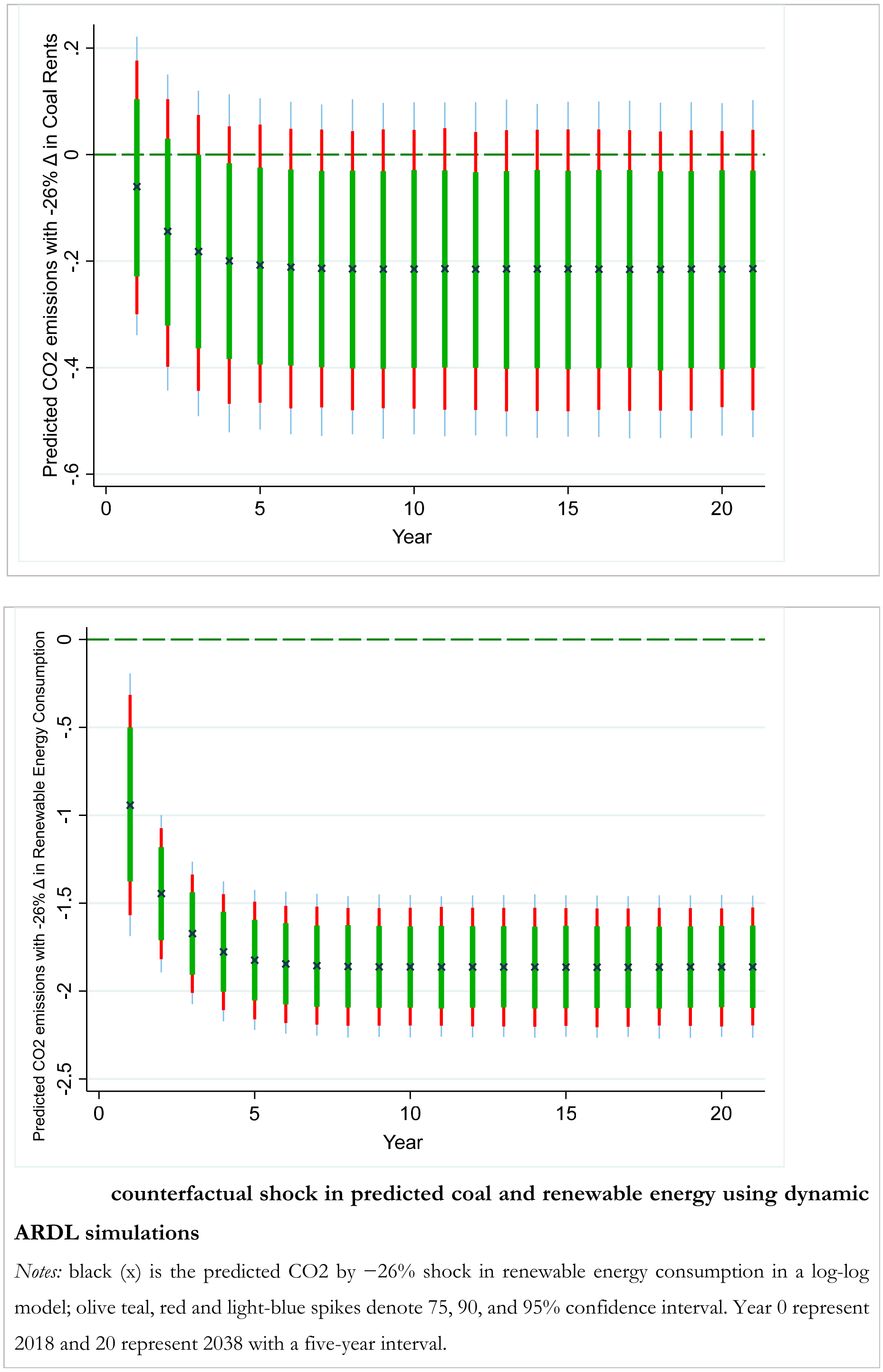


Fig. 8. counterfactual shock in predicted coal and renewable energy using dynamic ARDL simulations
Notes: black (x) is the predicted CO2 by −26% shock in renewable energy consumption in a log-log model; olive teal, red and light-blue spikes denote 75, 90, and 95% confidence interval. Year 0 represent 2018 and 20 represent 2038 with a five-year interval.

index in reducing carbon emission in Japan, that is, as the economy increases GDP per capita, more renewable energy will be consumed, and thus the quality of the environment will be improved. This is furthered supported by the increase in explanatory power, that is, the r-squared value of 0.666 which implies that 67% of the variation in the CO2 mission can be explained by the explanatory variables with ECI as an interaction term.

Generally, both ARDL and dynARDL estimate shows that a policy that either reduces reliance on coal energy or investment in renewable energy sources in Japan will present negative effects on carbon emission indicating that decrease in the use of energy factors might lead to decrease in carbon emission. To check for the effects of decreasing marginal returns of coal rent and renewable energy on carbon emission, the pledge by Japan to reduce

Table 6
Pointwise derivatives using KRLS.

lnCO2	Avg.	SE	T	P > t	P-25	P-50	P-75
lnRGDP	0.304	0.037	8.173	0.000	0.196	0.335	0.414
lnRNW	−0.018	0.006	−2.998	0.004	−0.037	−0.016	0.002
lnATP	0.095	0.024	3.991	0.000	0.063	0.086	0.128
lnCOR	0.001	0.004	0.323	0.748	−0.003	0.005	0.011
ECI	0.015	0.009	1.611	0.114	0.009	0.017	0.026
lnRGDPECI	0.002	0.001	2.322	0.025	0.001	0.002	0.003
Diagnostics							
Lambda	0.055	Sigma	6.000	R^2	0.973	Obs.	49
Tolerance	0.049	Eff. Df	13.100	Looloss	0.310	F-test	

Avg. Is the average marginal effect; SE is the standard error; P-25, P-50, and P-75 represent 25th, 50th, and 75th percentile. Legend: CO2 represents Carbon emissions; RGDP represents Real GDP per capita; RMW represents renewable energy consumption; ATP represent Air Transport; COR represent Coal Rents; ECI represents Economic Complex

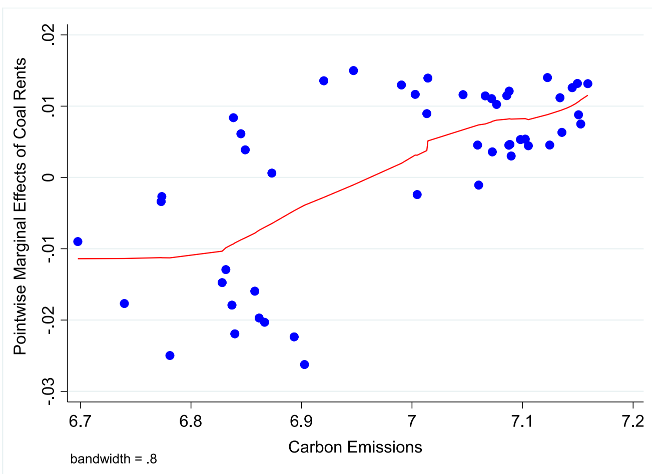


Fig. 9a. Representation of Pointwise marginal effect of renewable energy consumption.

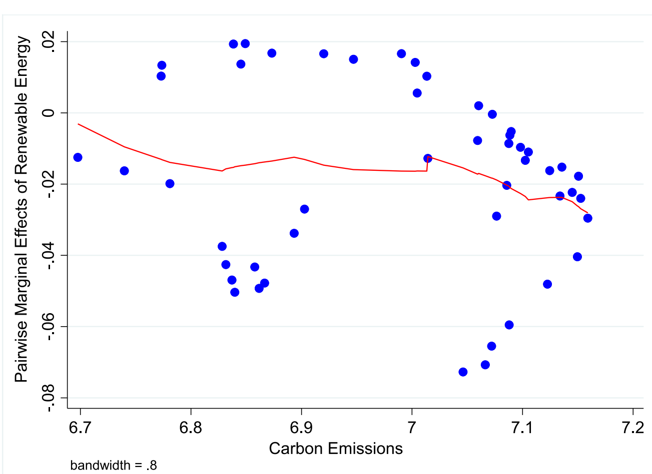


Fig. 9b. Representation of Pointwise marginal effect of renewable energy consumption.

[1] Carbon Brief (2018). Available at https://www.carbonbrief.org/carbon-brief-profile-japan.

emissions by ~26% in2030[1] was incorporated via the dynARDL estimation, with an allowance for a 20-year window for this to be achieved i.e. 2018 – 2038. The plots showing the dynARDL simulation are presented in Fig. 8a and Fig. 8b. Fig. 8a simulations expose that −26% shock in the estimated coal rents increases carbon emission in the first period of 2018 but the emission decelerates thereafter. Similarly, Fig. 8b simulations reveal that −26% shock predicted renewable energy elevate carbon emission in the first period of 2018, but the emission decreases thereafter. Both plots showed that even with the continual consumption of energy, carbon emission is on the decline.

5.2. Kernel-based regularized least squares (KRLS)

To further strengthen the arguments presented in this study, a machine learning methodology is adopted to assess and establish causal relationships among the variables. In this section, pointwise derivatives were estimated using KRLS to determine the causal-effect relationship among the studied variables. The overall predicting power of the model (Table 6) is 0.973 indicating that explanatory variables explained 97.3% of the variation in CO2 emission. Reporting the average marginal effect, it is observed the mean pairwise marginal effects of CO2, real GDP per capita, renewable energy, air transport, coal rent, economic index, and interaction term are 0.31%, −0.02%, 0.10%, 0.001%, 0.015%, and 0.002% respectively. The probability value of each variable at a 1% significance level means that only coal rent and economic index are not significant, hence evidence of causal-effect relationship is spotted in two variables. Furthermore, the long-term effects of variability of renewable energy and coal rents and their effects on carbon emission are examined by plotting the pointwise derivative of coal rent and renewable energy again carbon emission (Fig. 9a and Fig. 9b).

Fig. 9a reveals the varying marginal effect of coal rents on carbon emission. It can be observed that the lower level of coal rents usage increases the carbon emission at a higher level until it reaches a point where increasing coal rents usage increases the carbon emission. This connotes the negative impacts of coal rent consumption on the environment. Similarly, Fig. 9b reveal the varying marginal effect of renewable energy on carbon emission, it shows that a higher level of renewable energy consumption increases the carbon emission at a higher level. In other words, both renewable energy and carbon emission first move at the same pace until a threshold point is reached where the lower level of renewable energy increases the higher level of carbon emission.

6. Conclusion and policy directions

This study employed a dynamic autoregressive distributed lag model (dynARDL) for an analysis of Japan's energy policy mix for the period of 1970–2018. Presenting two cases estimation – with or without interaction variable, the study account for the role of economic complexities in policy designs while investigating long and short-term relationship using ARDL, dynARDL, and Kernel-Based Regularized Least squares (KRLS) to capture future counterfactual shocks. The findings revealed that both ARDL and dynARDL revealed a significant long-term relationship with some variables such as real GDP per capita, renewable energy, and economic index. This finding is similar to the work of [36,52]. In the same vein, variables such as air transport are significant in the short run. The interaction (GDP and ECI) term introduced are also a significant predictor of carbon emission in both the long-run and short-run. Furthermore, both ADRL and simulated dynARDL are useful in producing plot estimates and confidence intervals.

There are two major policy takeaways from this study: first, while coal energy emits more CO_2, renewable energy depletes the latter; secondly, the economic complexities index does not have any impact in abating the environmental degradation, but when it interacted with real GDP per capita, it plays a significant role in reducing the environmental degradation. Based on this, the government of Japan should formulate a policy that will curb the consumption of unclean or non-renewable energy sources. However, in setting plans, for achieving environmental targets, policy simulation suggests that both coal and renewable energy may have parallel outcomes. Also, the policy that will promote economic growth and the economic complexity index of the country should be considered. A limitation to this analysis, however, is the choice of simulation shocks. An accurate selection of several shocks will thus guide policymakers in what the government need to consider, a clean energy source or reduction in nonrenewable energy source. Policymakers are to maintain the balance between GDP per capita and ECI while trying to eradicate the adverse impact of the environment through the utilization of energy from renewable energy sources.

CRediT authorship contribution statement

Festus Fatai Adedoyin: Conceptualization. **Ilhan Ozturk:** SupervisionSupervising, and manuscript, Writing – review & editing. **Festus Victor Bekun:** literature search. **Phillips O. Agboola:** design. **Mary Oluwatoyin Agboola:** Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] IPCC, Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, in: R.K. Pachauri, L.A. Meyer (Eds.), IPCC, Geneva, Switzerland, 2014, p. 151.
[2] IPCC AR4 SYR Appendix Glossary" (P DF). Retrieved 14 December 2008.
[3] European Environment Agency: reportGreenhouse Gas Emission Trends and Projections in Europe 2007, EEA Report No 5/2007.
[4] B. Dogan, B. Saboori, M. Can, Does economic complexity matter for environmental degradation? An empirical analysis for different stages of development, Environ. Sci. Pollut. Res. 26 (2019) 31900–31912, https://doi.org/10.1007/s11356-019-06333-1.
[5] U.S. Environmental Protection Agency, Global Greenhouse Gas Emissions Data, Retrieved 30 December 2019. The burning of coal, natural gas, and oil for electricity and heat is the largest single source of global greenhouse gas emissions. Available at, https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data. (Accessed 2 January 2021).
[6] A.J. Jarvis, D.T. Leedal, C.N. Hewitt, Climate-society feedbacks and the avoidance of dangerous climate change, Nat. Clim. Change 2 (9) (2012) 668–671.
[7] G. Gozgor, M. Can, Does export quality matter for CO2 emissions? Evidence from China, Environ. Sci. Pollut. Res. 24 (3) (2017) 2866–2875.
[8] S. Dinda, Environmental Kuznets curve hypothesis: a survey, Ecol. Econ. 49 (4) (2004) 431–455.
[9] C.A. Hidalgo, The Dynamics of Economic Complexity and the Product Space over a 42 Year Period. CID Working Paper, Harvard University, 2009, p. 189.
[10] C.M. Sweet, D.S.E. Maggio, Do stronger intellectual property rights increase innovation, World Dev. 66 (2015) 665–677.
[11] Olimpia Neagu, Mircea C. Teodoru, The relationship between economic complexity, energy consumption structure and greenhouse gas emission: heterogeneous panel evidence from the EU countries, Sustainability 11 (2) (2019) 497. https://doi:10.3390/su11020497.
[12] H. Rüstemoglu, A.R. Andrés, Determinants of CO2 emissions in Brazil and Russia between 1992 and 2011: a decomposition analysis, Environ. Sci. Pol. 58 (2016) 95–106.
[13] C. Marques, A. Fuinhas, J. Manso, Motivations driving RE in European countries: a panel data approach, Energy Pol. 38 (2010) 6877–6885.
[14] M. Aguirre, G. Ibikunle, Determinants of RE growth: a global sample analysis, Energy Pol. 69 (2014) 374–384.
[15] S. Rafiq, H. Bloch, R. Salim, Determinants of renewable energy adoption in China and India: a comparative analysis, Appl. Econ. 46 (22) (2014) 2700–2710.
[16] M. Salahuddin, M.A. Habib, U. Al-Mulali, I. Ozturk, M. Marshall, M.I. Ali, Renewable energy and environmental quality: a second-generation panel evidence from the Sub Saharan Africa (SSA) countries, Environ. Res. 191 (2020) 110094.
[17] IEA, World Energy Outlook 2015, International Energy Agency, Paris, 2015.
[18] S. Carley, State RE electricity policies: an empirical evaluation of effectiveness, Energy Pol. 37 (2009) 3071–3081.
[19] P. Sadorsky, RE consumption, CO2 emissions and oil prices in the G7 countries, Energy Econ. 31 (2009) 456–462.
[20] N. Apergis, J.E. Payne, RE consumption and economic growth: evidence from a panel of OECD countries, Energy Pol. 38 (1) (2010) 656–660.
[21] A.N. Menegaki, Growth and renewable energy in Europe: a random effect model with evidence for neutrality hypothesis, Energy Econ. 33 (2) (2011) 257–263.
[22] A. Ohler, I. Fetters, The causal relationship between renewable electricity generation and GDP growth: a study of energy sources, Energy Econ. 43 (2014) 125–139.
[23] E. Dogan, I. Ozturk, The influence of renewable and non-renewable energy consumption and real income on CO 2 emissions in the USA: evidence from structural break tests, Environ. Sci. Pollut. Control Ser. 24 (11) (2017) 10846–10854.
[24] B. Ozcan, I. Ozturk, Renewable energy consumption-economic growth nexus in emerging countries: a bootstrap panel causality test, Renew. Sustain. Energy Rev. 104 (2019) 30–37.
[25] R. Hausmann, C.A. Hidalgo, S. Bustos, M. Coscia, A. Simoes, M.A. Yildirim, The Atlas of Economic Complexity: Mapping Paths to Prosperity, MIT Press, Cambridge, MA, USA, 2014, 2014; Available online: https://s3.amazonaws.com/academia.edu.documents/30678659/HarvardMIT_AtlasOfEconomicComplexity_Part_I.pdf?A. (Accessed 1 October 2018).
[26] S. Zhu, R. Li, Economic complexity, human capital and economic growth: empirical research based on cross-country panel data, Appl. Econ. 49 (38) (2016) 3815–3828.
[27] C.A. Hidalgo, B. Klinger, A.L. Barabasi, R. Hausmann, The product space conditions the development of nations, Science 317 (2007) 482–487.
[28] J. Yin, M. Zheng, J. Chen, The effects of environmental regulation and technical progress on CO2 Kuznets curve: an evidence from China, Energy Pol. 77 (2015) 97–108.
[29] K.R. Kaufmann, B. Davidsdottir, S. Garnham, P. Pauly, The determinants of atmospheric SO2 concentrations: reconsidering the environmental Kuznets curve, Ecol. Econ. 25 (2) (1998) 209–220.
[30] S. Nathaniel, S.A.R. Khan, The nexus between urbanization, renewable energy, trade, and ecological footprint in ASEAN countries, J. Clean. Prod. (2020) 122709.
[31] M. Guarnieri, J.R. Balmes, Outdoor air pollution and asthma, Lancet 383 (9928) (2014) 1581–1592.
[32] A. Sharif, S.A. Raza, I. Ozturk, S. Afshan, The dynamic relationship of renewable and nonrenewable energy consumption with carbon emission: a global study with the application of heterogeneous panel estimations, Renew. Energy 133 (2019) 685–691, https://doi.org/10.1016/j.renene.2018.10.052.
[33] Nicholas Apergis, James E. Payne, Kojo Menyah, Yemane Wolde-Rufael, On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth, Ecol. Econ. 69 (11) (2010) 2255–2260, https://doi.org/10.1016/j.ecolecon.2010.06.014.
[34] A.A. Azlina, N.H. Mustapha, Nik, Energy, economic growth and pollutant emissions nexus: the case of Malaysia, Procedia - Soc. Behav. Sci. 65 (2012) 1–7, https://doi.org/10.1016/j.sbspro.2012.11.082.
[35] A.N. Ajmi, S. Hammoudeh, D.K. Nguyen, J.R. Sato, On the relationships between CO2 emissions, energy consumption and income: the importance of time variation, Energy Econ. 49 (2015) 629e638, https://doi.org/10.1016/j.eneco.2015.02.007, 2015.
[36] C.F. Tang, B.W. Tan, The impact of energy consumption, income and foreign direct investment on carbon dioxide emissions in Vietnam, Energy 79 (2015) 447e454, https://doi.org/10.1016/j.energy.2014.11.033.
[37] K. Menyah, Y. Wolde-Rufael, CO 2 emissions, nuclear energy, renewable energy and economic growth in the US, Energy Pol. 38 (6) (2010) 2911–2915.
[38] U. Soytas, R. Sari, B.T. Ewing, Energy consumption, income, and carbon emissions in the United States Ecol, Econ. Times 62 (3) (2007) 482e489.
[39] C. Miao, D. Fang, L. Sun, Q. Luo, Q. Yu, Driving effect of technology innovation on energy utilization efficiency in strategic emerging industries, J. Clean. Prod. 170 (2018) 1177–1184.
[40] C. Miao, D. Fang, L. Sun, Q. Luo, Q. Yu, Driving effect of technology innovation on energy utilization efficiency in strategic emerging industries, J. Clean. Prod. 170 (2018) 1177–1184, 2018.
[41] Worldwatch Institute, Analysis: Nano Hypocrisy?, 16 January 2008. Available at, https://www.enn.com/articles/29401-analysis–nano-hypocrisy?. Retrieved 12 December 2020.
[42] D.S. Lee, D.W. Fahey, A. Skowron, M.R. Allen, U. Burkhardt, Q. Chen, A. Gettelman, The Contribution of Global Aviation to Anthropogenic Climate Forcing for 2000 to 2018, Atmospheric Environment, 2020, p. 117834.
[43] W. Schäfer Andreas, Ian A. Waitz, Air transportation and the environment, Transport Pol. 34 (2014) 1–4, https://doi.org/10.1016/j.tranpol.2014.02.012.
[44] Oxford Economics, Aviation – the Real World Wide Web, Report, Oxford, 2008.
[45] G. Mooney, C. Cal Muckley, D. Don Bredin, Prospective costs for the aviation

sector of the emissions trading scheme (2014), in: A. Dorsman, T. Gök, M.B. Karan (Eds.), Perspectives on Energy Risk, Springer Berlin Heidelberg, 2014, pp. 203–220.
[46] Daniel Balsalobre-Lorente, Oana Madalina Driha, Festus Victor Bekun, Festus Fatai Adedoyin, The asymmetric impact of air transport on economic growth in Spain: fresh evidence from the tourism-led growth hypothesis, Curr. Issues Tourism (2020), https://doi.org/10.1080/13683500.2020.1720624.
[47] S.A. Sarkodie, P.A. Owusu, How to apply the novel dynamic ARDL simulations (dynardl) and Kernel-based regularized least squares (krls), MethodsX [online] 7 (October) (2020) 101160, https://doi.org/10.1016/j.mex.2020.101160. Available from:.
[48] A.H. Shabbir, J. Zhang, J.D. Johnston, S.A. Sarkodie, J.A. Lutz, X. Liu, Predicting the influence of climate on grassland area burned in Xilingol, China with dynamic simulations of autoregressive distributed lag models, PloS One 15 (4) (2020), e0229894.
[52] Manuel Frondel, Nolan Ritter, Christoph M. Schmidt, Colin Vance, Economic impacts from the promotion of renewable energy technologies: the German experience, Energy Pol. 38 (8) (2010) 4048–4056, https://doi.org/10.1016/j.enpol.2010.03.029.