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RESEARCH ARTICLE

Environmental implication of offshore economic activities in Indonesia: a dual analyses of cointegration and causality

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Abstract

Global warming issues have become a pertinent theme for many economies and policy initiatives. The Indonesian economy is no exception as government officials and stakeholder are working seriously to decouple carbon emission from economic growth. It is on this premise that the present study attempts to investigate the nexus between the environmental implication of offshore economic activities, economic growth, energy use, and environment (CO_2) with the integration of foreign direct investment (FDI) and trade openness over recent time series data from 1980 to 2017. A series of analysis were conducted with Pesaran's autoregressive distributed lag (ARDL) methodology and the Granger causality test as estimation techniques over the outlined variables. Empirical findings from ARDL long-run (elasticity) shows that economic growth is significantly positively associated with carbon emissions at the initial stage but a negative association is established at lags 1 and 2. A significant positive relationship is witnessed between economic growth and FDI. Also, statistical positive relationship is observed between economic growth and energy use, while an inverse relationship is observed between openness and economic growth. For causality analysis, we observe that a unidirectional causality is running from economic growth to foreign direct investment at 5% significant level. This outcome is in support of the growth-induced FDI hypothesis in Indonesia. Furthermore, a one-way causality is seen from energy to openness, CO_2 emissions, and from FDI to CO_2 emissions while there is a feedback causality between openness and CO_2 emissions. The findings of this study have implications to the environmental quality of Indonesia via economic growth; hence, the higher and better the economic growth of the country, the lesser the carbon emissions and the better the environmental quality. This proposition aligns with the pollution halo hypothesis (PHH), where FDI inflow enhances economic growth as well as impacts energy consumption and reduces carbon emissions in the host country.

Keywords Carbon dioxide (CO_2) emissions · Offshore production · Energy use · Openness · Economic growth · FDI · Indonesia

JEL classification C32 · C33 · Q43 · Q50 · Q58

Introduction

The linkage between the economic growth and environment cannot be separated from the both the domestic and international economic activities. Among the economic activities that can be viewed both from the domestic and international aspects is production as it links to investments (foreign and domestic) and trade (import and export) (Sarkodie and Strezov 2019; Balsalobre and Álvarez-Herranz 2016). Every country or region making a progress in their trajectory to the economic growth must have witnessed increasing utilization of energy that may impact negatively on the environmental quality through great emissions of CO_2. The increase in energy consumption is associated with a spark in industrial production which is connected to both investment and trade; this will definitely cause environmental problems. Offshore

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economic activities, which imply economic activities across boundaries of countries, are the economic activities that happed in Indonesia which are transferred from other countries into Indonesia. This, as it concerns foreign direct investment (FDI) and trade, is at the center of coordinating the industrial and productive activities in most developing economies because of less preventive policies by the host countries. Foreign investors have literally shifted their economic activities and practices to the developing countries with less preventive measures towards the impacts of these foreign industries to their environments (Mabey and McNally 1999). Even though FDI role is becoming controversial and debatable, the relative and significant increase in economic growth of Indonesia is not exempted from the boost on the industrial activities in the country in which the foreign direct investment (FDI) and trade are inclusive.

It is worth mentioning that FDI encourages and promotes economic growth and development in the host country (Alfaro et al. 2010). Foreign direct investment (FDI) has proved to be a means of financing external economic activities and has equally served as a uniting force between the savings and investments domestically (Bustos 2007; Ndikumana and Verick 2008). Apart from savings and making available funds for investments, FDI also induces economy by the provision of positive externalities, technology, and skill transferring from the industrialized nations to the developing nations (Lee, 2013; Shahbaz et al. 2015a, b). Offshore economic activities which account for FDI and trade include outsourcing, relocating, or planting of foreign industries into another country due to some factors such as easy access to cheap or less-expensive labors and market location for the products, and tax incentives could induce a massive economic growth but to the detriment of the host countries because of the excessive energy consumption by those foreign-owned companies (Shahbaz et al. 2015a, b). This is called the pollution haven hypothesis (PHH), which acknowledged the less concern of the host country towards the harm of the foreign firms to the environmental quality of the host because of less-stringent policies to curtail FDI excesses (Cole and Elliott 2003). In most times, foreign firms are encouraged to make and expand their investment in an economy with less-stringent environmental laws to boost their productive activities; this is called the industrial flight hypothesis (Asghari 2013). Shifting a bit from the pollution haven hypothesis and industrial flight hypothesis where the FDI is working and flourishing to the detriment of the environment, FDI could also be a tool of improving the quality of environment in the host economy. This is attainable when FDI comes in with advanced technological equipment and energy-efficient technology with disciplined and better management principles which will eventually lead to the enhancement of the environmental quality in the host economy. This is in agreement with the argument of Shahbaz et al. (2015a, b), hypothesized as the pollution halo hypothesis, where FDI enhances economic growth which impacts energy consumption and carbon emission favorably in the host country. Furthermore, the trade perspective is also addressed as trade-induced CO_2 emissions. We consider production, import, and export as they relate to greenhouse gas emissions.

Most productions are undertaken with great energy consumption from either fossil fuel or coal. The fossil fuel or coal could be imported and exported, and the goods produced with these sources could also be imported or exported. If Indonesia imports fossil fuel from India for the sole aim of production by the companies domiciled in Indonesia, this could be classified as trade-induced CO_2 emissions and is expected to be included in the calculation of the environmental impact even though it is still debatable. The importer and the exporter of the CO_2 are Indonesia and India, respectively, and it is sometimes called territorial-based emissions because it reflects emissions within the country's geographical boundaries (Lamb et al. 2014). Because of the surging of economic growth and industrialization, the greenhouse gas emissions from industries, transportations, and power generation are equally increasing. It is projected that CO_2 emissions of Indonesia will grow and more than double in the next few years (Barnard 2017).

However, as the poor quality of the environment is always linked to unchecked economic and industrial activities of industries, firms or individuals, and most often the poorly economic regulations, usually affect the quality of the environment negatively. This is what generates the pollution haven hypothesis by Cole and Elliott (2003). Environmental regulations have economic and welfare effects; thus, any analysis concerning the welfare effects of variations in regulations should consider both economic and environmental effects as it concerns the public welfare. Upon this, we integrate FDI and trade openness in our model setting in an attempt to investigate and report clearly the environmental implication of offshore economic activities by linking among the economic growth, energy use, and environment (CO_2).

The novelty of this study to the energy economics and environment literature is the incorporation of both the FDI and trade openness in the analysis framework to drive home the environmental impact of offshore economic activities in Indonesia where little has been documented in the previous literature. This study measures the offshore economic activities by FDI and trade openness as additional variables to make the model multivariate. This aids in the avoidance of the omitted variable bias which previous studies fail to address. The present study utilizes both the dynamic autoregressive distributed lag (ARDL) methodology and ARDL-bounds to determine the cointegration, and Granger causality to detect the direction of causality among the outlined variables. This investigation is timely and worthwhile, given the position of

Indonesia to the Paris pledge, and being among the Southeast Asian countries that are exposed to the danger of the environmental degradation via industrial activities and the threat from the rising sea level, it is very important to research on the economy and aid the policy-makers with findings for better environmental improvement of the country.

The remainder of this study is structured in this manner: the "A synopsis on the Indonesian economy" section presents a brief synopsis on the Indonesian economy and the brief review of previous related works in a nexus style among the choice variables (GDP and CO_2 emissions, GDP and trade openness, FDI and GDP, FDI and CO2 emissions, and trade openness and CO_2 emissions). The "Data, methodology, and empirical findings" section presents the data with theoretical background and methodology, and presents the empirical results and discussions of the findings; and the "Concluding remark and policy implication" section presents the concluding part with the policy implications.

A synopsis on the Indonesian economy

Indonesia is ranked as the 16th biggest economy and the largest in Southeast Asia and the 4th biggest CO_2 emitter in 2015 (Azmy 2019). Indonesia has been identified as among the fast-growing developing economies from the Southeast Asian region with a well-manageable debt-to-GDP ratio (Fullerton et al. 2019). According to the economic outlook, the economic growth rate of Indonesia is forecasted to be average 5.3% from 2016 until date. Indonesian economy has been a center of focus because of its proactive action of improving on deforestation but rapidly increasing its greenhouse emissions in other sectors (Huguet et al. 2011).

However, it is pertinent to note that most of the vibrant developing economies (Indonesia inclusive) accelerating in economic activities are equally accelerating in greenhouse gas emissions. The economic growth often leads to uncontrolled utilization of natural resources and excessive energy consumption which causes environmental damage and pollution if not well managed. This is a clear indication that the relationship or link between the economic growth and CO_2 emissions is unavoidably inseparable following the impact of energy use which is a connecting factor between economic growth and CO_2 emission. The relationship could be positive portraying a complimentary growth (in this case economic growth is growing at the expense of the environment quality) or negative showing that while economic growth is trending upward, the CO_2 emissions are decreasing (in this case, the economy is growing while impacting positively to the quality of the environment). Indonesia has been identified as prospective Southeast Asia's biggest economy and the world's 4th largest greenhouse gas emitter after the likes of the USA, China, and India. This means that the economic growth and the greenhouse gas emission are almost growing in the same rate. They are expected to be in the same direction of upsurging if appropriate low-carbon development initiatives (LCDI) are not taking to make the economic growth more environmentally friendly. No doubt, this alert has prompted the country to peg its emissions cut target at 43rd percent by 2030 while targeting to deliver the annual economic growth of 5.6 and 6% in the next 25 years. It is said of Indonesia that it can overcome further environmental degradation by not adhering to the method of countries such as China to avoid their experience which is battling with pollution following the activities that have aided them to walk out of poverty into higher income categories (Andersen 2019). As attributed to the Indonesian Planning Minister, Bambang Brodjonegoro in his report made available to the joint initiative of World Resources Institute and a global research group "Indonesia wants high economic growth void of environmental sacrifice" (Kadarusman and Pramudya 2019; Sustainable Business, JAKARTA, Reuters, 2019). He went further to outline ways of attaining and sustaining the target such as adopting policies to foster agricultural productivity and prevention of deforestation, improving waste management, and shifting from fossil fuel energy to renewable energy. With effective implementation of these policies, it will amount to reduction in greenhouse gas emissions. Nevertheless, the vision of the country to shift to a low-carbon economy would amount to nothing if the country still slacks in curtailing the excessive use of coal. Currently, the country is still relying on fossil fuels to sustain its economy. Out of this, coal, gas, and oil are generating 59%, 23%, and 6.2% of electricity, respectively, while renewable energy only accounts for 13% of electricity (Andersen 2019).

Review of related literature

The literature review examined and analyzed the related studies by revisiting the relationship that exists between the chosen variables (GDP and CO_2 emissions, GDP and trade openness, FDI and GDP, FDI and CO_2 emissions, and trade openness and CO_2 emissions). The review of the past related works will be tailored to the principles of relationship style among the chosen variables.

Studies analyzing the relationship between economic growth GDP and CO_2 emissions

Many research works have been done in focus on the relationship between the economic growth and carbon emissions but no substantial agreement has been struck. Some of the literature are of opinion that positive relationship exists, while others are of contrary opinion with the positive relationship view based on their findings. The inconclusiveness of the findings and the non-unified views have left the subject open for researchers to study. Some of the studies that have researched on this subject are Akadiri et al. (2019a), Akadiri et al. (2019b), Akadiri and Akadiri (2019), Akadiri et al. (2018)Emir and Bekun (2019), Alola and Alola (2018), Shi et al. (2016), Twerefou et al. (2015), Omotor (2015), Lee (2013), Narayan and Sharma (2015), Boopen and Vinesh (2011), and Acharya et al. (2009). Furthermore, Balsalobre-Lorente et al. (2018, b) in their study found the existence of an N-shaped relationship between economic growth and CO_2 emissions. They also found that economic growth has a positive impact on CO_2 emissions. Udemba (2019) in his work on China found a positive relationship between GDP and CO_2 emissionsBekun et al. (2019a, b) join the strands of studies that found among others that economic growth increases carbon dioxide emissions. Alola et al. (2019a, b) in their work found a significant nexus of carbon emissions with gross domestic product (GDP). Emir and Bekun (2019) in their work found a positive relationship between economic growth and CO_2 emissions in Romanian economic performance cum energy intensity. Akadiri et al. (2019b) found a bi-directional transmission among economic growth and carbon emission. Sarkodie and Strezov (2019) found a negative relationship between economic growth and pollution in their work in developing countries. Akadiri et al. (2019a, b) in their studies found no significant relationship between real income (GDP) and per capita of carbon emissions. Al-mulali et al. (2015) found a positive relationship between economic growth and pollution both in the short and long-run. Bakhsh et al. (2017), in their findings on Pakistan economic study in relation with CO_2 emissions, conclude that GDP has a negative relationship with CO_2 emissions. Shi et al. (2016) applied a panel study across the different regions of China and came with a non-unified result, some showing positive relationship while others showed negative relationship between economic growth and CO_2 emissions. Twerefou et al. (2015), in their work on Ghana economy as it relates economic growth and CO_2 emissions, found a negative connection between economic growth of Ghana and carbon emissions. Omotor (2015) researched on some ECOWAS countries and found a positive relationship between GDP and environmental quality (CO_2 emissions). A study on the G20 countries by Lee (2013) confirmed a negative relationship between economic growth and CO_2 emissions. Boopen et al. (2011) researched on the connections between GDP and carbon emissions and found a negative relationship with emphasis on human activities that coordinates the pollution pattern. Sharma (2011) in his work found a positive effect of the economic growth on CO_2 pollutions. Acharya (2009) found a positive relationship between GDP and CO_2 emissions which he backs his argument on the effect of foreign direct investment (FDI) on the CO_2 pollutions.

Studies analyzing the relationship between economic growth GDP and trade openness

Many research works have been done with regard to the connectivity of GDP and trade openness. Hye (2012), applying the ARDL approach to study Pakistan economy with respect to its relationship with openness, found a negative relationship between GDP and trade openness. Sinha et al. (2017, b), investigating the next 11 countries in a panel setting, also found an inverse relationship between carbon emissions and trade openness. However, several other scholars have found positive relationship between emission pollutant (CO_2) and economic growth. For instance, using ARDL, Akadiri et al. (2019a) found a positive significant relationship between the trade and GDP. In the case of Ghana economy, Shahi (2012) found a positive connection between trade openness and economic growth. Investigating Ivory Coast economy with regard to trade openness, Kebo (2017) found a significant positive impact of trade on the economic growth of the country. Also, in Ghana economy, Kwame Asiedu, 2013came up with a finding that proved a positive relationship between economic growth and trade openness. On Nigerian economic performance as regards to trade openness, Nduka et al. (2013) confirmed a significant positive relationship between economic growth and trade. Marelli and Signorelli (2011), investigating the China and India economic performance based on trade openness, found a positive relationship between economic growth and trade openness. Lim and Kim (2011), research on 61 countries which include both developed and developing countries, found a positive relationship for the developed countries while that of the developing economies depicts a negative relationship. Barua et al. (2015) did a work on the same theme and found a positive relationship between economic growth and trade.

In recent times, the carbon-income function has been augmented with several macroeconomic indicators like energy consumption, mobile use, and trade openness. For instance, Balsalobre-Lorente (2019) found that agriculture activities and trade activities increase emission pollutant in BRICS economies. Furthermore, for the Spanish case, Balsalobre-Lorente and Shahbaz (2016) investigated the carbon-income with the inclusion of energy innovation, research and development (R&D), and trade openness. The study empirical finding validates an inverse relationship between research and development and environmental quality over the examined period. This outcome is also in line with the study of Balsalobre-Lorente et al. (2018, b) for EU-5 countries.

Studies analyzing the relationship between economic growth GDP and FDI

The literature on the connection between GDP and FDI has generated some debated grounds, with some scholars in support of the positive connection while others are in support of the negative connectivity between the two variables. Many others found causality (uni-directional and bi-directional) between GDP and FDI. Analysis of the connection between GDP and FDI on 41 developing countries was made using the GETS methodology and found a negative effect on economic growth. Udemba (2019) in his work on China found a positive relationship between GDP and FDI. Garcia-Santana et al. (2016) found FDI positively contributing to the economic development of Spain. FDI is found impacting the economic growth of Spain for over 40 years (Villa Verde & Maza 2012). Using the Toda Yamamoto Granger causality in panel studies by Ericsson and Irandoust (2001), they found a bi-directional transmission between GDP and FDI for Sweden, uni-directional transmission for Norway, and no transmission for Denmark and Finland. Chakraborty and Basu (2002) researched the causality between economic growth and FDI and found a uni-directional transmission passing from economic growth to FDI. Also, in a panel study of East and South African regions, Anyanwu (2012) found that FDI impacts economic growth. In their work on the Gulf Cooperation council, Toone (2012) found no causality between economic growth and FDI. Likewise, the work on Ghana by Frimpong et al. (2007) found no causality between the FDI and growth. Also, a work on Malaysia by Karimi and Yusop, 2009shows no causality between the two variables. Ericsson and Irandoust (2001) have equally worked on the causality between the FDI and growth, and found no causality between them.

Studies analyzing the relationship between foreign direct investment and CO_2 emissions

Studies that have investigated the relationship between FDI and CO_2 emissions are many but with little or less agreement on a unified finding. Just like any other subjects of research, many researchers are of opinion that a positive relationship exists while some other scholars are of contrary views. Sarkodie and Strezov (2019) in their work found a strong impact of energy use on carbon dioxide emissions because of the FDI impacting force on the economy validating the pollution haven hypothesis. Shahbaz et al., 2019) examine the association between (FDI) and CO_2 emissions for the Middle East and North African (MENA) region in 1990–2015, and the N-shape connection is revealed between FDI and carbon emissions. Akadiri et al. (2019a, b) in their work found that globalization index led to a 0.914% decrease in metric ton per capita of CO_2 emissions in the short-run, and a 1.769% decrease in metric ton per capita of CO_2 emissions in the long-run. Globalization is a platform through which FDI flourished in the modern-day global economy; this means that whenever globalization is considered in any writing, it accommodates both trade and FDI. Also, in attempt to establish a connection between FDI and carbon emissions, the work of Paramati et al. (2017) found that both FDI and stock market developments play a significant role in promoting clean energy consumption which impacts positively on carbon emissions. Ben Kheder and Zugravu-Soilita (2008) did a research work on pollution and found that the pollution emitting from the activities of the French industries are significantly positive with pollution in the host countries. Also, Ben Kheder and Zugravu-Soilita (2008) studying on China economy found positive relationship between FDI and CO_2 emissions. A research work on OECD countries by Pazienza (2015) shows a negative association between FDI and environment (agricultural and fishing sectors). A research work on Nigeria by Ajide and Adeniyi (2010) found a positive relationship between FDI (in terms of the activities of the multinational oil and gas firms) and CO_2 emissions. Omri (2013) observed that FDI inflows cause increase or raise CO_2 emissions substantially by 0.19%. In his panel work of 110 developed and developing countries, Shahbaz et al. (2014) found a positive relationship between the foreign investments and CO_2 emissions in terms of environmental degradation. Blanco et al. (2013) demonstrated in his studies that FDI inflow has a positive relationship with environmental degradation. Also, Talukdar and Meisner (2001) in their studies found a negative significant connection between FDI (from developed countries) and CO_2 emissions in developing countries.

Studies analyzing the relationship between trade openness and CO_2 emissions

Many research works have considered this subject, either as a joint analysis with energy consumption or as financial development. In the work of Balsalobre-Lorente et al. (2018, b), they found that the interaction between trade openness and economic growth exerts a positive impact on carbon emissions. A research work was done on newly industrialized countries (NIC) by Hossain (2011); he found a uni-directional short-run transmission from trade openness to carbon emissions. Shahbaz (2011) investigated the South African economy with respect to interaction between trade openness and environmental performance; he found a long-run relationship between trade opens and environmental quality. Muhammad and Fatima (Muhammad and Ghulam Fatima, 2013) did a work on Pakistan economy as regards the relationship among economic growth, carbon emissions, financial development, and trade openness. He, among others, found a significant impact on carbon emission from trade openness. Furthermore, in Turkey, Ozturk and Acaravci (2013) did a work for the period of 1960–2007, and they found that trade openness has a positive relationship with carbon emissions. Shahbaz (2013) did a research work on China using financial development, energy use, and trade openness; he found feedback among the variables. Also, Shabaz (2013) researched on Indonesia economy as regards the relationship among financial development, energy use, and trade openness; he found a negative relationship between trade openness and carbon emissions.

Data, methodology, and empirical findings

Data

Indonesian annual data have been used for the period that covered from 1980 to 2017 in the current research. Data on GDP per capita (constant 2010 US$), CO_2 emissions (metric tons per capita), energy use (kilogram of oil equivalent per capita), foreign direct investment, net inflows (bop, current US$), and trade openness (IMP (constant 2010 US$)+EXP (constant 2010 US$)/GDP (constant 2010 US$)) are all sourced from the 2018 World Development Indicator (WDI), and these are the selected variables for this study. The chosen variables are all expressed in their natural logarithm form to achieve homoscedasticity. Definitions and summary of the variables are displayed in Table 1.

Preliminary analysis includes summary statistics that is presented in Table 2 which reports averages, standard divisions, maximum, and minimum. In addition, information about symmetry and peakness of the variables are computed as revealed by the normality test (Jarque-Bera) and Kurtosis, respectively. We observe that trade openness displays the highest average and lowest is seen as carbon emission. All variables show light tails with kurtosis less than three. In regard to symmetry, all outlined variables are normally distributed as reported by the Jarque-Bera probability with the exception of FDI.

Methodological process

The methodological framework employed in the present study includes the following: test for unit root, descriptive statistics, optimal lag selection criterion, dynamic autoregressive distributed lag (ARDL), and causality testing. The author employed applications like Dickey-Fuller (ADF-Dickey and Fuller 1981), Phillips-Perron (Perron 1990), and Kwiatkwoski-Phillips-Schmidt-Shin (KPSS 1992) unit root tests to determine if the selected variables are stationary at level, at first difference or mixed order. The vector autoregressive (VAR) lag order selection criteria were employed for optimal lag selection, and this was done with the Akaike information criteria (AIC). Descriptive statistics was employed for the identification of the mean, minimum, and maximum range of the selected variables, and the dynamic autoregressive distributed lag (ARDL), with 3 lags together with ARDL-bound estimation (both short-run and long-run) as proposed by (Pesaran et al. 2001), is employed in this study to estimate both the long-run and the short-run connections among the economic growth (GDP), carbon emission, energy use, openness, and FDI. Pairwise Granger causality is equally employed in order to trace and establish the nexus that exist among the variables which assisted in investigating and reporting clearly the environmental implication of offshore economic activities by linking among the economic growth, energy use, and environment (CO_2) in a cointegrated and causality framework.

Model specifications

The current study seeks to analyze the environmental implication of offshore economic activities by linking the selected variables in a linear manner with economic growth (GDP) as a dependent variable and others (CO_2 emissions, energy use, openness, and FDI) as independent variables. The research model specification and the entire estimation approach of this study are based on ARDL approach to establish and analyze the linear relationship that exist among the chosen variables (economic growth (GDP), CO_2 emissions, energy use, trade openness, and FDI). The econometric form is expressed as:

$$Y = ACO_2{}^{\theta 1}\mathrm{EU}^{\theta 2}\mathrm{OPEN}^{\theta 3}\ \mathrm{FDI}^{\theta 4} \quad (1)$$

Y represents income (GDP per capita) in a constant local currency, A represents the level of technology use in the country, and it is considered to be fixed (CO_2 represents environment (CO_2 emissions), EU represents energy use, and OPEN

Table 1 Variables and their measurements

Full description of the variables	Short names of the variables	Measurement/calculations
GDP per capita	GDP	Constant 2010 US$ (logGDP)
Carbon dioxide	CO_2 emissions	Metric tons per capita
Energy use	Energy use	kg of oil equivalent per capita
Trade openness	Open	Export+import/GDP (all in US$)
Foreign direct investment, net inflows	FDI	Bop, current US$

Source: authors' compilation

Table 2 Descriptive statistics of the variables

	LN CO_2	LNGDP	LNEN	LNFDI	LNOPEN
Mean	1.303061	212.06313	662.3227	5.38E+09	861.39933
Median	1.256117	200.47029	689.6921	1.84E+09	845.05718
Maximum	2.559750	375.49519	893.9110	2.51E+10	1.24E+08
Minimum	0.642650	111.88870	377.6794	− 4.55E+09	540.25568
Std. dev.	0.512549	7,519,449.	178.8905	8.12E+09	241.85896
Skewness	0.506956	0.576213	− 0.355925	1.282490	0.147126
Kurtosis	2.583998	2.357670	1.698413	3.315933	1.576598
Jarque-Bera	1.901705	2.756065	3.484693	10.57498	3.345041
Probability	0.386411	0.252074	0.175109	0.005054	0.187773
Sum	49.51632	8.06E+08	25,168.26	2.04E+11	3.27E+09
Sum sq. dev.	9.720147	2.09E+15	1,184,067.	2.44E+21	2.16E+16
Observations	38	38	38	38	38

Source: authors' compilation

and FDI represent trade openness and foreign direct investment inflow, respectively. The subscripts ($\theta 1$, $\theta 2$, $\theta 3$, $\theta 4$, and $\theta 5$) denote the return to scale which is linked to the variables in use. All the series are converted and expressed in the logarithm in order to express the model in a linear form instead of a non-linear form. There is a level of spurious findings always emanating from a non-linear specification which will tend to mislead the audience of this study and stall the policy-making process and purpose. The functional relationship of the present study leverages after the study of Gokmenoglu and Taspinar (2016):

$$Y_t = A + \theta_1 CO_{2t} + \theta_2 EU_t + \theta_3 OPEN_t + \theta_4 FDI_t + \varepsilon_t \quad (2)$$

From Eq. (2), the relationship among the economic growth, CO_2 emissions, energy use, trade openness, and FDI is estimated while holding the technology (A) fixed. This is later framed in a linear model while keeping the technology fix as follows:

$$Y_t = \theta 0 + \theta_1 CO_{2t} + \theta_2 EU_t + \theta_3 OPEN_t + \theta_4 FDI_t + \varepsilon_t \quad (3)$$

where Y denotes GDP per capita, CO_2 denotes environment (CO_2 emissions), EU represents energy use, OPEN denotes trade openness, and FDI denotes foreign direct investment inflows, ε and t denote error term and time index.

Estimation procedure

Stationarity test

Time series data or country-specific analyses are always believed to have unit root; for this purpose and in a way of avoiding spurious estimation and analyses, it is important for the stationarity test to be conducted. This study employed some of the generally accepted techniques like Dickey-Fuller (ADF) (Dickey & Fuller, 1981), Phillips-Perron (PP) (Perron 1990), and Kwiatkwoski-Phillips-Schmidt-Shin (KPSS 1992) to determine if the variables have a non-unit root. The stationarity was tested and the output confirms that the data are non-stationary and that all variables are integrated into the order of one I (1). Furthermore, the tests account for structural break dates. The break dates show the new governments striving with reforms such as fiscal policy, monetary policy, and political climate. The reforms include improving the investment climate and boosting the growth, which is tailored towards expanding investments in public infrastructure, minimizing the stringency of public (government) regulations, and opening up new sectors of the economy to private investment. These reforms are targeted at opening the Indonesian's economy for the attraction of foreign investors with caution as it concerns welfare and environmental issues. The appearance of 2010 as among the accounted break dates is in line with global financial crises that hit the global economy from 2008 to 2010/2012. The results of the above-mentioned techniques and the structural break are displayed in Table 4.

ARDL-bound testing approach

The unit root tests confirmed the integration of all the variables to order of one I (1) as reported in Tables 3 and 4 for all conducted test, both traditional and break-point unit root. All outlined tests are in harmony of order one integration. The current study chose ARDL because of its advantage in displaying its estimation results in lags order thereby giving in the relationship history of the selected variables. This aids the author to accommodate the relationship trend in the analyses without being bias at the initial result which might obstruct the expectations of the author, and it also helps in policy formulation in a research study. This is the case where the lag order of the result comes in a mixed order of negativity and

Table 3 Unit root test

Variables	At level		1st diff		Conclusion
	With intercept	Intercept and trend	With intercept	Intercept and trend	
ADF					
LNGDP	2.4167	− 0.1808	− 3.8835***	− 4.4473***	I (1)
LN CO_2	− 1.1018	− 3.1497	− 6.0682***	−5.9783***	I (1)
LNENERGY	− 1.8802	− 1.6098	− 6.6229***	− 4.5693***	I (1)
LNOPEN	− 1.3805	− 3.4355*	− 8.0636***	− 7.9614***	I (1)
LFDI	− 1.7971	− 2.7493	− 6.4656***	− 6.3490***	I (1)
PP					
LNGDP	2.4167	− 0.4372	− 3.8835***	− 4.4320***	I (1)
LN CO_2	− 0.8677	− 3.1395	− 7.0744 ***	− 6.8957***	I (1)
LNENERGY	− 1.1387	− 1.4931	− 6.7505***	− 7.3533***	I (1)
LNOPEN	− 1.2398	− 3.4326*	− 8.0636***	− 7.9614***	I (1)
LNFDI	− 1.0017	− 2.5300	− 6.4526***	− 6.3099***	I (1)
KPSS					
LNGDP	0.7176**	0.1634**	0.3958*	0.0977	
LN CO_2	0.6905**	0.0662	0.1449	0.1440*	
LNENERGY	0.7185**	0.1810**	0.1868	0.1681**	
LNOPEN	0.6820**	0.0637	0.0738	0.0676	
LNFDI	0.5032**	0.1559 **	0.1321	0.0743	

*Significant at 10%

**Significant at 5%

***Significant at 1%

Lag length based on SIC; probability based on MacKinnon (1996) one-sided *p* values and Kwiatkowski-Phillips-Schmidt-Shin (1992)

Source: authors' computation

positivity, where in one lag, the variables may be displaying positive association with the dependent variable but with a negative relationship in next lag. This will expose the variables that needed to be managed for a certain time period, even though they are not yielding the expected result in the current time, but considering the positive trend in the

Table 4 Break-point unit root tests

Variable	ADF	*p* value	Lag	Break date	CV (1%)	CV (5%)
Level						
LNGDP	− 7.884	< 0.01***	5	1997	− 5.348	− 4.8598
LN CO_2	− 7.491	< 0.01***	9	2010	− 5.348	− 4.8598
LNENERGY	− 4.932	0.0401**	0	1989	− 5.348	− 4.8598
LNOPEN	− 4.1705	0.275	8	1998	− 5.348	− 4.8598
LNFDI	− 3.8550	0.4651	9	1997	− 5.348	− 4.8598
1st diff						
LNGDP	− 12.490	< 0.01***	9	1997	− 5.348	− 4.8598
LN CO_2	− 7.286	< 0.01 ***	1	2012	− 5.348	− 4.8598
LNENERGY	− 7.886	< 0.01***	9	1990	− 5.348	− 4.8598
LNOPEN	− 11.1344	< 0.01***	0	1988	− 5.348	− 4.8598
LNFDI	− 6.1463	< 0.01***	0	1984	− 5.348	− 4.8598

*Significant at 10%

**Significant at 5%

***Significant at 1%

Source: authors' computation

subsequent lags, it could be handled with care, bearing in mind of the possible future impact. ARDL approach has been misunderstood by many researchers and this led to a general conclusion that it is limited to only where the order of integration is mixed, but in actual sense, ARDL does not select the order of integration (see Pesaran et al. 1998 & 2001). Hence, the current study adopted the ARDL-bound approach.

ARDL specifications The econometric specification of ARDL equation can be written as follows:

$$Y = \theta_0 + \theta_1 CO_2 + \theta_2 EU + \theta_3 OPEN + \theta_4 FDI + \varepsilon \qquad (4)$$

Y represents the log of GDP per capita, CO_2 represents the log of carbon (CO_2 emissions) emissions, EU represents the log of energy use, while OPEN and FDI stand for the log of openness and log of foreign direct investment inflows, respectively, and ε represents the error term. θ_0, θ_1, θ_2, and θ_3 denote the coefficients of the variables in the model. Equation (4) is expanded from the ARDL dynamic equation to contain both the long-run (ARDL-bound testing) and short-run (error correction tests) equations. The two models (long-run and short-run) are expressed in Eqs. (5) and (6) as follows:

$$Y_t = \theta_0 + \theta_1 Y_{t-1} \theta_2 CO_{2t-1} + \theta_3 EU_{t-1} + \theta_4 OPEN_{t-1} + \theta_5 FDI_{t-1} + \varepsilon_t \qquad (5)$$

$$\Delta Y_t = \theta_0 + \theta_i \sum_{i=1}^{n} Y_{t-i} \theta_j \sum_{j=1}^{n} C0_{2t-j} + \theta_k \sum_{k=1}^{n} EU_{t-k} + \theta_{n\sum_{n=1}^{n}} OPEN_{t-n} + \theta_{m\sum_{n=1}^{n}} FDI_{t-m} + ECM_{t-1} + \varepsilon_t \qquad (6)$$

From Eq. (5), θ_0, θ_1, θ_2, θ_3, and θ_4, and, from Eq. (6), θ_0, θ_I, θ_J, θ_K, θ_N, and θ_m are the long-run coefficients, and the parameters in Eq. (6) are the short-run coefficients. Δ in Eq. (6) denotes the 1st difference of the variables, while ECM_{t-1} shows the speed of adjustment over a certain period of time which is usually considered as the long-run. Before the proper estimation of ARDL dynamic tests, it is vital to check the long-run association among the choice variables using the bound testing procedure.

The hypothesis with a claim of no cointegration in the model is as follows:

$$H0 : \theta_0 = \theta_I = \theta_J = \theta_K = \theta_N = 0 \text{ against the alternative hypothesis } H1 : \theta_0 = \theta_I = \theta_J = \theta_K = \theta_N \neq 0 \text{ with a view of cointegration.}$$

The ascertainment of cointegration is done by comparing the estimated F-statistics (T-statistics) with critical lower I (0) and upper I (0) bound values. Bound testing is done to check for long-run associations and often denoting Wald or F-test. According to Pesaran et al. (2001), the estimated F-statistics value with bound testing approach is compared with the estimated critical value, and if the estimated value of F-test is greater than the tabulated value, it shows that the long-run association between variables exists. Hence, the null hypothesis of no cointegration is rejected. However, if the F-statistics is lesser than the lower bound critical value, the alternative hypothesis of the existence of cointegration is rejected, while the result becomes inconclusive when the F-statistics is in between the two (upper and lower) bounds critical values. The ARDL-bound approach test model employs a more general approach to the conditional error correction model (ECM). This approach, combined with the option of imposing restriction on intercept, trend, and or both as shown in the general model of Eq. (6), is expressed in the above specification. Hence, the results are presented in Table 5.

Table 5 reports the results of both the long-run (ARD-bound testing) and the short-run (ECT) derived with autoregressive distributive analyses (ARDL) estimation. The optimum lag selection is 4 as indicated by the Akaike criteria (AIC). The Akaike information criteria were considered appropriate for the optimum lag selection because of its superior properties over other criteria (see Shahbaz & Rahman, 2012). According to the output from the AIC, lag 4 is considered appropriate for the sample size of this analysis. The ECM coefficient with a negative sign and highly significant at even 1% shows the speed of adjustment in restoring the disjointed equilibrium in the dynamics model; it is also an indicator that there is a convergence among the variables in the long-run to an equilibrium (see Bannerjee et al. 1998). The cointegration equation for this study revealed (ECT = −0.1748) 18% (approximately) speed of adjustment to the equilibrium path on GDP from the impact of CO_2 emissions, energy use, trade openness, and FDI on an annual basis. The outcome of the estimation shows a mixed pattern of relationship between the variables and the economic growth (GDP). The displayed result in Table 5 confirms the ARDL long-run (elasticity) of economic growth is significantly positively associated with carbon emissions. This finding is in consonance with the findings of Alola et al. (2019a, b) in their study on large economies of Europe and of Emir and Bekun (2019) in their work on Romania, but this finding changed in the 1st and 2nd lags with negative and significant relationship between GDP and CO_2 emissions. This means that the economic growth of Indonesia induces carbon emissions in the initial stage, but in the 1st and 2nd lags, both in the short-run and long-run, the otherwise is the case, meaning that economic growth of Indonesia is reducing the carbon emission which is a laudable trend for the economy. This finding corresponds to the findings of Sarkodie and Strezov (2019) who found a negative relationship between the economic growth and pollution in their work on developing countries, and also in the work of Akadiri et al.

Table 5 ARDL dynamic estimates of GDP equation

Variables	Coefficients	SE	*T*-statistics	Probability value
Short-run				
D(LN CO_2)	0.1240	0.023	5.344	0.0002***
D(LN CO_2 (− 1))	− 0.176	0.081	− 2.458	0.0008***
D(LN CO_2 (− 2))	− 0.880	0.410	− 2.146	0.0500**
D(LNENERGY)	0.842	0.040	2.105	0.0176**
D(LNENERGY (− 1))	− 0.169	0.030	− 5.709	0.0002***
D(LNENERGY (− 2))	− 0.162	0.062	− 2.583	0.04501**
D(LNOPEN)	− 0.542	0.426	− 1.247	0.2411
D(LNOPEN (− 1))	0.804	0.426	1.885	0.0861*
D(LNOPEN(− 2))	1.687	0.394	4.280	0.0013***
D(LNFDI)	3.045	0.606	5.020	0.0004***
D(LNFDI (− 1))	− 6.404	2.035	− 3.146	0.0093***
D(LNFDI (− 2))	− 4.775	1.528	− 3.124	0.0097***
CointEq (− 1)*	− 0.174	0.023	− 7.649	0.0000***
Long-run				
LN CO_2	0.1240	0.023	5.344	0.0002***
LN CO_2 (− 1)	− 7.030	2.970	− 2.366	0.0374**
LN CO_2 (− 2)	8.680	3.450	2.513	0.0288**
LNENERGY	0.842	0.420	2.004	0.0455**
LNENERGY (− 1)	− 1.610	1.010	− 1.594	0.1393
LNENERGY (− 2)	− 0.542	1.340	− 0.404	0.692
LNFDI	3.045	1.634	1.863	0.0894*
LNOPEN	− 0.542	0.435	− 1.246	0.239
LNOPEN (− 1)	− 0.740	0.252	− 2.940	0.0134**
LNOPEN (− 2)	0.884	0.252	3.499	0.0050***
C	− 6.060	2.650	− 2.290	0.0427**
Bound test (long-run)				
F-statistics	8.6***	*K* = 4, at 1%	I (0) bound = 3.74	I (1) bound = 5.06
T-statistics	− 7.23***	*K* = 4, at 1%	I (0) bound = − 3.4	I (1) bound = − 4.6
Wald test (short-run)				
F-statistics	13.25***			
p value	0.0004			
Serial correlation test				
F-statistics	0.634			
Heteroskedasticity test				
F-statistics	0.975			

*Rejection of the null hypothesis at the 1%

**Rejection of the null hypothesis at the 5%

***Rejection of the null hypothesis at the 10%

Sources: authors' computation

(2019a). Numerically, a 1% increase in the carbon emissions significantly impacted the economic growth positively by 12%, but surprisingly to the good of the Indonesian economy, this trend was altered in 1st and 2nd lags. Hence, a 1% increase in the economic growth reduces carbon emission by 18% and 9% in both first and second lags, respectively. Also, this finding shows a positively significant relationship between economic growth and energy use (as expected). This portrays a success trend in balancing the economic growth and the environmental quality because whenever the economy is growing, there is every tendency that the energy consumption will be high in the economy, but where the energy consumption is efficiently moderated and carefully shifted to a more conservative renewable energy, it will go a long way to reduce the carbon (CO_2) emission as we found in the growth relationship with the CO_2 emissions in the 1st and 2nd lags. This research finding is in agreement with the findings of Sarkodie and Strezov (2019) that validate the pollution haven hypothesis for Indonesia at the initial stage, but with the careful observation of a change of pattern in both 1st and 2nd lags, a decline shown in total emissions in 2016 countered the findings from Sarkodie and Strezov (2019). Also, the projection of Barnard (2017), where it is projected that CO_2 emissions of Indonesia will grow more than double in the next few years, is equally faulted with this finding and the decreasing trend of CO_2 emissions in Fig. 1. This is in agreement with the works of Emir and Bekun (2019) for the Romania study and Paramati et al. (2017) and Balcilar et al. (2019) for their Pakistan study. A negative and significant relationship is found between openness and economic growth, but positive and significant relationship was observed between openness and growth in the 1st and 2nd lags. This is a true picture of a trade deficit and import-oriented country like Indonesia. Indonesia trade openness does not reflect a favorable one because of its over-dependence on importation of primary and non-technological products, but a reversal was observed in the lag periods and the same trend was observed even in the long-run which is a good sign and healthy to the economy of Indonesia. This finding is in agreement with the works of Hye (2012) for Pakistan who found a negative relationship between economic growth and openness, and of Akadiri et al. (2019a) for Ghana with a positive result. As for the findings on the relationship between the economic growth and FDI, the result shows a positive and significant relationship between the economic growth and foreign direct investment inflow in both the short-run and in the long-run. This shows that FDI is impacting favorably to the Indonesia economic performance which is yielding to the government reform policy of shifting from public to private investment, and it is healthy to the economy and at the same time very attractive to the foreign investors. This has an implication to the environmental quality of Indonesia via economic growth; hence, the higher and better the economic growth of the country, the lesser the carbon emissions and the better the environmental quality and the general welfare. This supports the pollution halo hypothesis by Shahbaz (2018b), where FDI enhances the economic growth which impacts the energy consumption and carbon emission favorably in the host country. This supports the findings of Paramati et al. (2017) in their work on G2O, OECD nations, and Anyanwu (2012).

Granger causality

The conventional regression will only show the relationship and impact with the level of the impact as significant or insignificant but does not really exhibit direct causation (transmission) which is behind the relationship among the variables adopted in any research studies. Not minding the fact that the applied (ECT) as employed in this very work shows causality (transmissions) among the variables, it is limited with the causality without much light to the direction (feedback) of the causality. Hence, this informed the choice of testing further to ascertain both the transmission and the direction of the transmission among the employed variables (GDP per capita, CO_2 emissions, energy use, trade openness, and FDI). In an attempt to identify the direction of the transmitting among the variables, the current study considered the pairwise Granger causality technique an appropriate approach to be employed. The theoretical background of the Granger causality is established in line with the Gregory and Hansen (1996) mode. The equation is expressed as follows:

$$Y_{1t} = c + \alpha_t + \gamma \Delta W_t(\lambda) + \delta_i Y_{2t} + \mu_t \qquad (7)$$

where Y_{1t} and Y_{2t} are of 1st difference (i.e., I (1)) and Y_{2t} represents the set of variables (GDP per capita, CO_2 emissions, energy use, openness, and FDI); $\Delta W_t(\lambda) = 1$ for $t > T\lambda$; otherwise, $\Delta W_t(\lambda) = 0$; $\lambda = T_a/T$ denotes the location where the structural break lies; T remains the sample size while T_a denotes the date of the occurrence of a structural break (1984, 1988, 1989, 1990, 1997, 1998, 2010, and 2012). Also, there is a need to check whether the error term μ_t in Eq. (7) is stationary at level I (0) or 1st difference I (1) through any of the ADF or PP techniques. If it is (i.e., μ_t) found to be consistent with I (1), it is assumed that the cointegration exists between Y_{1t} and Y_{2t}. If the statistical features of μ_t is established, one can use the bivariate vector autoregressive (VAR) model to

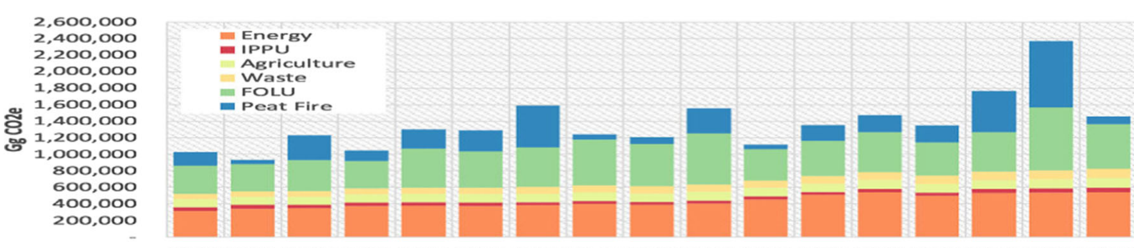

Fig. 1 Annual total growth of Indonesia emissions from 6 different sources of Indonesia's total emissions from 2000 to 2016. Emissions from peatland fires (blue), forestry and other land use ("FOLU"; green), waste (yellow), agriculture (pale green), industry ("IPPU"; red), and energy (orange) are shown. Emissions are shown in gigagrams of CO_2 equivalent ($GgCO_2e$, millions of tonnes). It is worth noting that the figures are self-reported. Source: Ministry of Environment and Forestry, Indonesia

estimate the Granger causality.

The VAR model can be expressed as follows:

$$Y_t = \theta_0 + \sum_{i=1}^{n} + \sum_{i=1}^{n} \alpha_i \Delta Y_{t-i} + \sum_{i=1}^{n} \delta_i \Delta \mathrm{CO}_{2t-i} + \sum_{i=1}^{n} \beta_i \Delta \mathrm{EU}_{t-i} + \sum_{i=1}^{n} \lambda_i \Delta \mathrm{OPEN}_{t-i} + \sum_{i=1}^{n} \gamma_i \Delta FDI_{t-i} + \varepsilon_t \quad (8)$$

$$C02_t = \theta_0 + \sum_{i=1}^{n} + \sum_{i=1}^{n} \alpha_i \Delta \mathrm{CO}_{2t-i} + \sum_{i=1}^{n} \delta_i \Delta Y_{t-i} + \sum_{i=1}^{n} \beta_i \Delta \mathrm{EU}_{t-i} + \sum_{i=1}^{n} \lambda_i \Delta \mathrm{OPEN}_{t-i} + \sum_{i=1}^{n} \gamma_i \Delta \mathrm{FDI}_{t-i} + \varepsilon_t \quad (9)$$

$$\mathrm{EU}_t = \theta_0 + \sum_{i=1}^{n} + \sum_{i=1}^{n} \alpha_i \Delta \mathrm{EU}_{t-i} + \sum_{i=1}^{n} \delta_i \Delta \mathrm{CO}_{2t-i} + \sum_{i=1}^{n} \beta_i \Delta Y_{t-i} + \sum_{i=1}^{n} \lambda_i \Delta \mathrm{OPEN}_{t-i} + \sum_{i=1}^{n} \gamma_i \Delta\Delta \mathrm{FDI}_{t-i} + \varepsilon_t \quad (10)$$

$$\mathrm{OPEN}_t = \theta_0 + \sum_{i=1}^{n} + \sum_{i=1}^{n} \alpha_i \Delta \mathrm{OPEN}_{t-i} + \sum_{i=1}^{n} \delta_i \Delta \mathrm{CO}_{2t-i} + \sum_{i=1}^{n} \beta_i \Delta \mathrm{EU}_{t-i} + \sum_{i=1}^{n} \lambda_i \Delta Y_{t-i} + \sum_{i=1}^{n} \gamma_i \Delta\Delta \mathrm{FDI}_{t-i} + \varepsilon_t \quad (11)$$

$$\mathrm{FDI}_t = \theta_0 + \sum_{i=1}^{n} + \sum_{i=1}^{n} \alpha_i \Delta \mathrm{POP}_{t-i} + \sum_{i=1}^{n} \delta_i \Delta \mathrm{CO}_{2t-i} + \sum_{i=1}^{n} \beta_i \Delta \mathrm{EU}_{t-i} + \sum_{i=1}^{n} \lambda_i \Delta \mathrm{OPEN}_{t-i} + \sum_{i=1}^{n} \gamma_i \Delta Y_{t-i} + \varepsilon_t \quad (12)$$

The current study applies the pairwise Granger causality which serves as a robust check to the findings from the error correction estimation. The pairwise Granger causality is shown in Table 6.

Table 6 encompassed and shows the result from the pairwise Granger causality test. The findings give credence to the revealing of the dynamic, ARDL-bound (long-run), and ECT (short-run) estimations above. It is established from the findings that uni-directional causation passing to foreign direct investment (FDI) from the economic growth (GDP) at 5% significant level. This is a signal of a good economic performance that poised on attracting investors. This is laudable and attests to the fact that the new government's striving with reforms such as fiscal policy, monetary policy, and political climate is yielding positive results by attracting FDI, hence GDP causing FDI. The reforms include improving the investment climate and boosting growth which is tailored towards expanding investments in public infrastructure, minimizing the stringency of public (government) regulations, and opening up new sectors of the economy to private investment. These reforms are targeted at opening the Indonesian's economy for the attraction of foreign investors with caution as it concerns welfare and environmental issues, and this finding is in consonance with the target. This finding is in support of the findings in the works of Nguyen and Ross (2017) and Peiris et al. (2016) on Vietnam and Chinese economy. The causality tests equally show uni-directional transmission passing from energy to openness, CO_2 emissions, and from FDI to CO_2 emissions while there is feedback causation between openness and CO_2 emissions. This established how the economic growth of Indonesia and the carbon emissions are impacted through the nexus among the selected variables. Thus, it is a clear indication that Indonesian economy is not far-fetched from the energy-induced growth considering the high dependence of the economy on manufacturing and industrial sectors. It gives vivid direction of the transmissions and how the environmental quality is impacted; hence, energy consumption is causing CO_2 emissions through (offshore) economic and industrial activities such as foreign investments. FDI with openness is equally causing CO_2 emissions respectively and this has environmental implication which can be either negative or positive. This is definitely going to be a pointer to policy-makers on how to frame policies to achieve a balanced economic growth with efficient energy use in others to maintain free lethal CO_2 emissions. The findings as it concerns energy use transmitting to CO_2 emissions are in agreement with the findings of Alola et al. (2019a, b) and Akadiri et al. (2019b).

Diagnostic test

A diagnostic test was carried out in an attempt to ascertain the stability of the analyses. The test was done with some estimations as regards to the normality, correlation, and stability of the analyses to ensure that the analysis and estimations are free from wrong estimations or misspecification which will lead to a doubt on the validity of our claims. The findings from the tests of serial correlation, normality test, and heteroscedasticity show that the study is normally distributed and free from any form of serial correlation (see the findings on the below of ARDL-bound test table immediately after bound test). The stability and reliability of the short-run and long-run ARDL model were checked with cumulative sum (CUSUM) tests and cumulative sum of square tests (CUSSUM) (Brown et al., 1975). The finding clearly indicates that the stability of the coefficients over the period researched is assured. The results are shown in Fig. 2.

Concluding remark and policy implication

This study integrates foreign direct investment (FDI) and trade openness in a multivariate setting as it attempts to investigate empirically the environmental implication of offshore economic activities. This is done by linking among the economic growth, energy use, and environment (CO_2) in a cointegrated and causality manner. The study is estimated with the combination of ARDL (dynamics)-bound tests and the pairwise Granger causality estimation approaches. Long equilibrium is established with findings of ARDL-bounds testing, and

Table 6 Granger causality result

Null hypothesis	*F*-statistics	Probability	Causality	Direction
LN CO_2→LNGDP	0.10049	0.9047	No	Neutral
LNGDP→ LN CO_2	1.85873	0.1728		
LNENERGY→LNGDP	0.03379	0.9668	No	Neutral
LNGDP→LNENERGY	0.01187	0.9882		
LNFDI→LNGDP	0.10113	0.9041	Yes	Uni-directional
LNGDP→LNFDI	3.72402	0.0355**		
LNOPEN→LNGDP	0.17012	0.8443	Yes	Uni-directional
LNGDP→LNOPEN	10.3056	0.0004***		
LNENERGY→LN CO_2	5.76815	0.0074**	Yes	Uni-directional
LN CO_2→LNENERGY	0.04614	0.9550		
LNFDI→LN CO_2	1.41649	0.2578	Yes	Uni-directional
LN CO_2→LNFDI	4.41186	0.0206**		
LNOPEN→LN CO_2	2.59832	0.0905*	Yes	Bi-directional
LN CO_2→LNOPEN	5.24343	0.0109**		
LNFDI→LNENERGY	0.34059	0.7140	No	Neutral
LNENERGY→LNFDI	1.61217	0.2157		
LNOPEN→ LNENERGY	1.00137	0.3789	Yes	Uni-directional
LNENERGY→ LNOPEN	5.66398	0.0080**		
LNOPEN→LNFDI	1.16011	0.3267	No	Neutral
LNFDI→LNOPEN	1.03677	0.3666		

*Rejection of the null hypothesis at 10%

**Rejection of the null hypothesis at 5%

***Rejection of the null hypothesis at 1%

Sources: authors' computation

robust check for confirmation of the long-run stability and ability to adjust after disequilibrium was done with error correction model (ECM). The output confirmed long-run equilibrium with the ability to adjust at −0.174%. Some key variables (such as CO_2 emissions, energy use, trade openness, and FDI) displayed a mixture of positive and negative both at an initial stage and at different lags with the economic growth, and all the independent variables are significant, in consideration to the output of the long-run association estimation from Table 5. It rightly depicts the relationship that is established between economic growth and the explanatory variables. The outcome of the estimation shows a mixed pattern of relationship between the variables and the economic growth (GDP). The displayed result in Table 5 confirms the ARDL long-run (elasticity) of economic growth is significantly positively associated with carbon emissions. But this finding changed in the 1st and 2nd lags with negative and significant relationship between GDP and CO_2 emissions. This means that economic growth of Indonesia induces carbon emissions in the initial stage, but in the 1st and 2nd lags, both in the short-run and

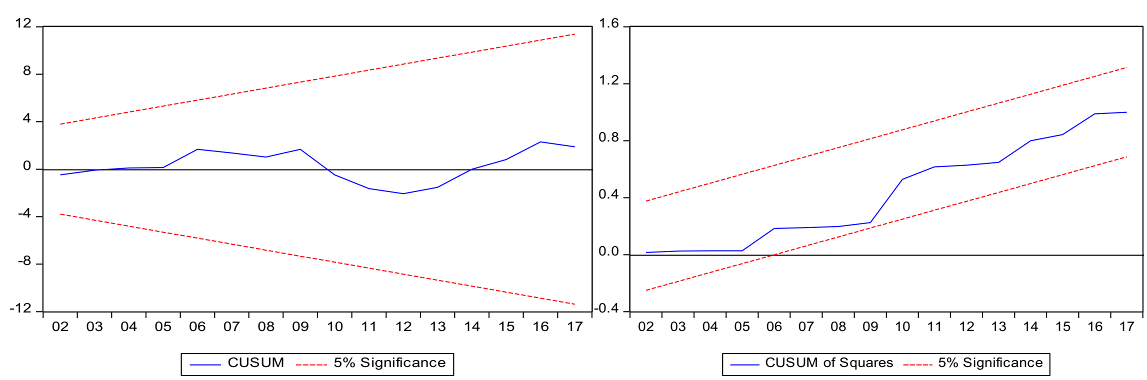

Fig. 2 Plot of the cumulative sum of square of recursive residuals. The conventional lines denote critical bounds at 5% significance level. Source: authors' computation

long-run, the otherwise is the case, meaning that economic growth of Indonesia is reducing the carbon emission which is a good trend for the economy. Also, findings showed a positively significant relationship between economic growth and energy use (as expected). This portrays a success trend in balancing the economic growth and the environmental quality because whenever the economic is growing, there is every tendency that the energy consumption will be high in the economy, but where the energy consumption is efficiently moderated and managed, and carefully shifted to a more conservative renewable energy, it will go a long way to reduce the carbon emission as we found in the growth relationship with the CO_2 emissions in the 1st and 2nd lags. A negative and significant relationship is found between openness and economic growth, but positive and significant relationship was observed between openness and growth in the 1st and 2nd lags. This is a true picture of a trade deficit and import-oriented country like Indonesia. Indonesia trade openness does not reflect a favorable one because of its over-dependence on importation of primary and non-technological products, but a reversal was observed in the lag periods, and the same trend was observed even in the long-run which is a good sign and healthy to the economy of Indonesia. As for the findings on the relationship between the economic growth and FDI, the result shows a negative but not significant relationship between the economic growth and foreign direct investment inflow in the short-run, while in the long-run, the relationship became significantly positive. This shows that FDI is impacting favorably Indonesia's economic performance which is yielding to the government reform policy of shifting from public to private investment, and it is healthy to the economy and at the same time very attractive to the foreign investors. This has implication to the environmental quality of Indonesia via economic growth; hence, the higher and better the economic growth of the country, the lesser the carbon emissions and the better the environmental quality. This support the pollution halo hypothesis by Shahbaz (2018b), where FDI enhance economic growth which impacts energy consumption and carbon emission favorably in the host country.

With the findings of this present study, which provides justifiable evidence of nexus transmissions among economic growth, CO_2 emissions, energy use, openness, and FDI, the government policy implication should be framed and centered on how to mitigate between energy intensity, openness, and FDI to sustain the present economic growth trend of Indonesia while reducing the CO_2 emissions in the economy. This should be done with an eye on the attraction of foreign investors with the environmental conscious policy which will balance the gains of the investors and the quality of environment. Also, cost-effective yardstick should be a better way of improving the efficiency and reduction of the energy intensity, thereby meeting up with its target of cutting emissions to 43rd percent in 2030 while targeting to deliver the annual economic growth of 5.6 and 6% in the next 25 years. The handlers of the economy should engage on energy security and diversification by shifting from crude and traditional energy-generating sources such as fossil fuel to a more conservative and renewable energy such as wind and solar sources of energy. Again, considering the causation among CO_2, FDI, and openness especially the feedback transmission between openness and CO_2 emissions, it provides important policy implications for controlling pollution emissions in Indonesia. Currently, the government of Indonesia provides incentives to foreign investors to create avenue for attracting FDI. No doubt, FDI plays an important contribution in the betterment of economy of any developing country like Indonesia, but this should not sway the attention of the government authorities from the environmental impact of the offshore (openness and FDI) economic activities in the country. With these implications in mind, adequate and balanced regulatory policies should be in place to moderate between the economic performance and environmental consequences of the offshore economic activities in Indonesia.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

Acharya J, Sahu JN, Sahoo BK, Mohanty CR, Meikap BC (2009) Removal of chromium (VI) from wastewater by activated carbon developed from tamarind wood activated with zinc chloride. Chem Eng J 150(1):25–39

Ajide KB, Adeniyi O (2010) FDI and the environment in developing economies: evidence from Nigeria. Environ Res J 4(4):291–297

Akadiri SS, Lasisi TT, Uzuner G, Akadiri AC (2018) Examining the causal impacts of tourism, globalization, economic growth and carbon emissions in tourism island territories: bootstrap panel Granger causality analysis. Curr Issue Tour:1–15

Akadiri AC, Saint Akadiri S, Gungor H (2019a) The role of natural gas consumption in Saudi Arabia's output and its implication for trade and environmental quality. Energy Policy 129:230–238

Akadiri SS, Bekun FV, Taheri E, Akadiri AC (2019b) Carbon emissions, energy consumption and economic growth: a causality evidence. Int J Energy Technol Policy 15(2–3):320–336

Akadiri SS, Akadiri AC (2019) The role of natural gas consumption in economic growth. Strateg. Plan. Energy Environ

Alfaro L, Chanda A, Kalemli-Ozcan S, Sayek S (2010) Does foreign direct investment promote growth? Exploring the role of financial markets on linkages. J Dev Econ 91(2):242–256

Alola AA, Alola UV (2018) Agricultural land usage and tourism impact on renewable energy consumption among Coastline Mediterranean Countries. Energy & Environment 29(8):1438–1454

Alola AA, Alola UV, Saint Akadiri S (2019a) Renewable energy consumption in coastline Mediterranean countries: impact of environmental degradation and housing policy. Environ Sci Pollut Res:1–13

Alola AA, Yalçiner K, Alola UV, Saint Akadiri S (2019b) The role of renewable energy, immigration and real income in environmental sustainability target. Evidence from Europe largest states. Sci Total Environ 674:307–315

Álvarez-Herranz A, Balsalobre-Lorente D, Shahbaz M, Cantos JM (2017) Energy innovation and renewable energy consumption in the correction of air pollution levels. Energy Policy 105:386–397

Andersen HS (2019) Urban sores: On the interaction between segregation, urban decay and deprived neighbourhoods. Routledge

Anyanwu JC (2012) Why does foreign direct investment go where it goes?: new evidence from African countries. Ann Econ Financ 13(2)

Asghari M (2013) Does FDI promote MENA region's environment quality? Pollution halo or pollution haven hypothesis. Int J Sci Res Environ Sci 1(6):92–100

Azmy K (2019) Carbon-isotope stratigraphy of the uppermost Cambrian in eastern Laurentia: implications for global correlation. Geol Mag 156(5):759–771

Balcilar M, Bekun FV, Uzuner G (2019) Revisiting the economic growth and electricity consumption nexus in Pakistan. Environ Sci Pollut Res 26(12):12158–12170

Bakhsh K, Rose S, Ali MF, Ahmad N, Shahbaz M (2017) Economic growth, CO2 emissions, renewable waste and FDI relation in Pakistan: new evidences from 3SLS. J Environ Manag 196:627–632

Balsalobre D, Álvarez-Herranz A (2016) Economic growth and energy regulation in the environmental Kuznets curve. Environ Sci Pollut Res:1–17

Balsalobre-Lorente D, Shahbaz M (2016) Energy consumption and trade openness in the correction of GHG levels in Spain. Bull Energy Econ 4(4):310–322

Balsalobre-Lorente D, Shahbaz M, Roubaud D, Farhani S (2018) How economic growth, renewable electricity and natural resources contribute to CO2 emissions? Energy Policy 113:356–367

Balsalobre-Lorente D, Driha OM, Bekun FV, Osundina OA (2019) Do agricultural activities induce carbon emissions? The BRICS experience. Environ Sci Pollut Res:1–17

Banerjee A, Dolado J, Mestre R (1998) Error-correction mechanism tests for cointegration in a single-equation framework. J Time Ser Anal 19(3):267–283

Barnard M (2017) Tesla & Google disagree about LIDAR—which is right. Clean Technica. web.

Barua A, Sawhney A (2015) Development policy implications for growth and regional inequality in a small open economy: the Indian case. Rev Dev Econ 19(3):695–709

Behera SR, Dash DP (2017) The effect of urbanization, energy consumption, and foreign direct investment on the carbon dioxide emission in the SSEA (South and Southeast Asian) region. Renew Sust Energ Rev 70:96–106

Bekun FV, Alola AA, Sarkodie SA (2019a) Toward a sustainable environment: nexus between CO2 emissions, resource rent, renewable and nonrenewable energy in 16-EU countries. Sci Total Environ 657:1023–1029

Bekun FV, Emir F, Sarkodie SA (2019b) Another look at the relationship between energy consumption, carbon dioxide emissions, and economic growth in South Africa. Sci Total Environ 655:759–765

Ben Kheder S, & Zugravu-Soilita N (2008) The pollution haven hypothesis: a geographic economy model in a comparative study

Boopen S, & Vinesh S (2011) On the relationship between CO2 emissions and economic growth: the Mauritian experience. In University of Mauritius, Mauritius Environment Outlook Report, http://www.csae.ox.ac.uk/conferences/2011-EDiA/papers/776-Seetanah.pdf Vol. 14, p. 2015

Brown RL, Durbin J, Evans JM (1975) Techniques for testing the constancy of regression relationships over time. J R Stat Soc Ser B Methodol 37(2):149–163

Bustos P (2007) Multilateral trade liberalization, exports and technology upgrading: Evidence on the impact of MERCOSUR on Argentinean firms. mimeo Universitat Pompeu Fabra

Chakraborty C, Basu P (2002) Foreign direct investment and growth in India: a cointegration approach. Appl Econ 34(9):1061–1073

Cheung YW, Lai KS (1997) Bandwidth selection, prewhitening, and the power of the Phillips-Perron test. Econometric Theory 13(5):679–691

Cole MA, Elliott RJ (2003) Do environmental regulations influence trade patterns? Testing old and new trade theories. World Econ 26(8):1163–1186

Cole MA, Elliott RJ, Fredriksson PG (2006) Endogenous pollution havens: does FDI influence environmental regulations? Scand J Econ 108(1):157–178

Dickey DA, Fuller WA (1981) Likelihood ratio statistics for autoregressive time series with a unit root. Econometrica: J Econometric Society 49:1057–1072

Emir F, Bekun FV (2019) Energy intensity, carbon emissions, renewable energy, and economic growth nexus: new insights from Romania. Energy Environ 30(3):427–443

Frimpong JM, & Oteng-Abayie EF (2007) Market returns and weak-form efficiency: the case of the Ghana stock exchange

Fullerton TM, Fullerton SL, Nazarian AD, & Solís O (2019) Borderplex economic outlook to 2020. UTEP Border Region Modeling Project

Garcia-Santana M, Moral-Benito E, Pijoan-Mas J, & Ramos R (2016) Growing like Spain: 1995–2007

Gregory AW, Hansen BE (1996) Practitioners corner: tests for cointegration in models with regime and trend shifts. Oxf Bull Econ Stat 58(3):555–560

Hossain MS (2011) Panel estimation for CO2 emissions, energy consumption, economic growth, trade openness and urbanization of newly industrialized countries. Energy Policy 39(11):6991–6999

Huguet C, Martrat B, Grimalt JO, Sinninghe Damsté JS, Schouten S (2011) Coherent millennial-scale patterns in U37k′ and TEX86H temperature records during the penultimate interglacial-to-glacial cycle in the western Mediterranean. Paleoceanogr Paleoclimatol 26(2)

Hye QMA (2012) Long term effect of trade openness on economic growth in case of Pakistan. Qual Quant 46(4):1137–1149

Irandoust JEM (2001) On the causality between foreign direct investment and output: a comparative study. Int Trade J 15(1):1–26

Kadarusman YB, Pramudya EP (2019) The effects of India and China on the sustainability of palm oil production in Indonesia: towards a better understanding of the dynamics of regional sustainability governance. Sustain Dev

Karimi MS, & Yusop Z (2009) FDI and economic growth in Malaysia

Keho Y (2017) The impact of trade openness on economic growth: the case of Cote d'Ivoire. Cogent Econ Finance 5(1):1332820

Lamb WF, Steinberger JK, Bows-Larkin, A, Peters GP, Roberts JT, Wood FR (2014) Transitions in pathways of human development and carbon emissions. Environmental Research Letters 9(1):014011

Lee JW (2013) The contribution of foreign direct investment to clean energy use, carbon emissions and economic growth. Energy Policy 55:483–489

Kwame Asiedu M (2013) Trade liberalization and growth: the Ghanaian experience

Lim KP, Kim JH (2011) Trade openness and the informational efficiency of emerging stock markets. Econ Model 28(5):2228–2238

Mabey N, McNally R (1999) Foreign direct investment and the environment. WWF-UK, Godalming, Surrey

Muhammad J, & Ghulam Fatima S (2013) Energy consumption, financial development and CO2 emissions in Pakistan

Narayan PK and Sharma SS (2015) Is carbon emissions trading profitable?. Economic Modelling 47:84–92

Ndikumana L, Verick S (2008) The linkages between FDI and domestic investment: unravelling the developmental impact of foreign investment in Sub-Saharan Africa. Dev Policy Rev 26(6):713–726

Nduka EK, Chukwu JO, Ugbor KI, & Nwakaire ON (2013) Trade openness and economic growth: a comparative analysis of the pre and post structural adjustmen
t programme (SAP) periods in Nigeria. Asian J Bus Econ 3(3.4)

Nguyen TH, Ross A (2017) Barriers and opportunities for the involvement of indigenous knowledge in water resources Management in the gam River Basin in north-East Vietnam. Water Alternatives 10:1

Nguyen TN, Wongsurawat W (2017) Multivariate cointegration and causality between electricity consumption, economic growth, foreign direct investment and exports: recent evidence from Vietnam. Int J Energy Econ Policy 7(3):287–293

MacKinnon JG (1996) Numerical distribution functions for unit root and cointegration tests. J Appl Econ 11(6):601–618

Marelli E and Signorelli M (2011) China and India: Openness, trade and effects on economic growth. The European Journal of Comparative Economics 8(1):129

MOTOR O (2015) Sustainability Report

Omri A (2013) CO2 emissions, energy consumption and economic growth nexus in MENA countries: evidence from simultaneous equations models. Energy Econ 40:657–664

Ozturk I, Acaravci A (2013) The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. Energy Econ 36:262–267

Paramati SR, Apergis N, Ummalla M (2017) Financing clean energy projects through domestic and foreign capital: the role of political cooperation among the EU, the G20 and OECD countries. Energy Econ 61:62–71

Pazienza P (2015) The environmental impact of the FDI inflow in the transport sector of OECD countries and policy implications. Int Adv Econ Res 21(1):105–116

Peiris JM, Cowling BJ, Wu JT, Feng L, Guan Y, Yu H, Leung GM (2016) Interventions to reduce zoonotic and pandemic risks from avian influenza in Asia. Lancet Infect Dis 16(2):252–258

Perron P (1990) Testing for a unit root in a time series with a changing mean. J Bus Econ Stat 8(2):153–162

Pesaran MH, Shin Y (1998) An autoregressive distributed-lag modelling approach to cointegration analysis. Econom Soc Monogr 31:371–413

Pesaran MH, Shin Y, Smith RJ (2001) Bounds testing approaches to the analysis of level relationships. J Appl Econ 16(3):289–326

Sarkodie SA, Strezov V (2019) Effect of foreign direct investments, economic development and energy consumption on greenhouse gas emissions in developing countries. Sci Total Environ 646:862–871

Shahbaz M, Tang CF, Shabbir MS (2011) Electricity consumption and economic growth nexus in Portugal using cointegration and causality approaches. Energy Policy 39(6):3529–3536

Shahbaz M, Solarin SA, Mahmood H, Arouri M (2013) Does financial development reduce CO2 emissions in Malaysian economy? A time series analysis. Econ Model 35:145–152

Shahbaz M, Loganathan N, Zeshan M, Zaman K (2015a) Does renewable energy consumption add in economic growth? An application of auto-regressive distributed lag model in Pakistan. Renew Sust Energ Rev 44:576–585

Shahbaz M, Nasreen S, Abbas F, Anis O (2015b) Does foreign direct investment impede environmental quality in high-, middle-, and low-income countries? Energy Econ 51:275–287

Shahbaz M, Balsalobre D, Shahzad SJH (2019) The influencing factors of CO 2 emissions and the role of biomass energy consumption: statistical experience from G-7 countries. Environ Model Assess 24(2):143–161

Shahi U (2012) Risk and Return Analysis on Common Stock Investment between Kumari Bank Ltd And Everest Bank Ltd (Doctoral dissertation, Office of the Dean Faculty of Management Tribhuvan University)

Shi K, Chen Y, Yu B, Xu T, Chen Z, Liu R, ... and Wu J (2016) Modeling spatiotemporal CO2 (carbon dioxide) emission dynamics in China from DMSP-OLS nighttime stable light data using panel data analysis. Applied Energy 168:523–533

Shin Y, Schmidt P (1992) The KPSS stationarity test as a unit root test. Econ Lett 38(4):387–392

Sinha A, Shahbaz M, Balsalobre D (2017) Exploring the relationship between energy usage segregation and environmental degradation in N-11 countries. J Clean Prod 168:1217–1229

Talukdar D, Meisner CM (2001) Does the private sector help or hurt the environment? Evidence from carbon dioxide pollution in developing countries. World Dev 29(5):827–840

Toone JE (2012) Mirage in the Gulf: examining the upsurge in FDI in the GCC and its legal and economic implications for the MENA region. Emory Int'l L Rev 26:677

Twerefou DK, Tutu KA, Botchway E, Darkwah S (2015) Willingness-to-pay for potable water in the Accra-Tema Metropolitan area of Ghana. Mod Econ 6(12):1285–1296

Twerefou DK, Adusah-Poku F, Bekoe W (2016) An empirical examination of the environmental Kuznets curve hypothesis for carbon dioxide emissions in Ghana: an ARDL approach. Environ Socio Econ Stud 4(4):1–12

Udemba EN (2019) Triangular nexus between foreign direct investment, international tourism, and energy consumption in the Chinese economy: accounting for environmental quality. Environ Sci Pollut Res 1-12

Villaverde J, Maza A (2012) Foreign direct investment in Spain: regional distribution and determinants. Int Bus Rev 21(4):722–733

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