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RESEARCH ARTICLE

# Triangular nexus between foreign direct investment, international tourism, and energy consumption in the Chinese economy: accounting for environmental quality

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**Abstract**
Recently, China is named among the most carbon dioxide ($CO_2$)-emitting countries in the world after the United State of America (USA). A major part of Chinese carbon dioxide emissions is as a result of offshore industrial activities which come into the economy as foreign direct investment (FDI). Following this, the present study seeks to investigate the nexus between $CO_2$ emissions, FDI, energy use, and tourism arrivals, and possibly to advise on who will bear the responsibility of offshore $CO_2$ emissions. Utilizing ARDL-bound testing and Granger causality approaches for both short- and long-run effects the author found that economic growth (GDP) has a positive relationship with both tourism arrivals, energy use, FDI, and $CO_2$.This contributes to heavy $CO_2$ emissions which the author classified as the outsourced/offshore $CO_2$emissions in China's FDI. Tourism arrivals have a bi-directional (feedback) causal relationship with energy use and a uni-directional causal relationship with $CO_2$(transmitting from tourism to $CO_2$). Both FDI and energy use have a bi-directional (feedback) causal relationship; $CO_2$, energy use, and tourism arrivals have a unidirectional relationship with GDP which established the triangular nexus causality among the variables and the impact on GDP. Hence, the policy implication should be geared towards implementing the policies and regulations that will checkmate and reduce the excesses of foreign firms to the environment quality of China and promote environmentally friendly economic activities.

**Keywords** $CO_2$ emissions · Energy use · FDI · Tourism arrivals · Offshore activities · Economic growth · China

**JEL classification** C32 · C33 · Q43 · Q50 · Q58

## Introduction

China is considered a hub of many commercial activities which translates into above-average use of energy. It is estimated that China's basic use of energy increased to 3billion tons oil equivalent, amounting to 23% of the global total (Wu and Chen, 2017, b). China in a quest to keep up with its fast pace of development through industrialization has considered the ever-rising request and use of the inadequate energy resources a major obstacle. For this, extensive policies to foster the sustainability of the energy use has been enforced such as the Energy Development Strategy Action Plan (2014–2020), the Thirteenth Five-year Plan for Electric Power Development, and Medium and Long-term Development Plan for Renewable Energy (Feng et al. 2013). Energy use has been intensified since the global economic activities are seriously shifting into an era of outsourced manufacturing goods and trade. China in particular has achieved a commendable economic growth over the past 3 years of improvement and liberalization. China's GDP has moved from a mere 6% to over 60% approximately (Zhang 2018). This rapid shift into trade and manufacturing is linked with a great cost of natural resources and the climatic change (Chen 2016).

The energy use is among the sources of carbon dioxide ($CO_2$) emissions, and this, with other greenhouse gases, is considered to account for global climate change (Wu and Chen 2017). In extant literature, a strong transmission is shown between economic activities (e.g., heavy industrial

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and manufacturing activities) and their adverse impacts on environmental quality, and this is agreed to be among the causes of environmental dilapidation through $CO_2$ emissions (Uchiyama 2016). Several advanced and developing countries are putting needed struggles to reduce and if possible to overcome the problem of increased $CO_2$ emissions. Following a unique framework (CGE model) that connects Chinese energy structure and economy, the work found that Chinese coal use measuring $CO_2$ pollution should grow to the highest sometime in the year 2020, while the country's total $CO_2$ emissions would increase to a maximum around 2030 (Tully 2016). Environmental problems are sensitive areas of worry not only for the community but also in terms of making economic selection (Sy et al. 2016). To curtail the inflammatory injuries of the $CO_2$ emissions to the global change has been among the worldwide struggles (Tamazian and Rao 2010). China is perceived as the global highest contributor of carbon dioxide after the USA and is facing serious pressure in a bid to reduce the world's climate change. This is the evidence of the outcome of the world's foremost concise climate treaty entered into force in Paris (Liu et al. 2018). China as a principal actor amid the parties involved has been tasked to look into reasonable improvement plans of reducing energy use and curtail $CO_2$ emissions.

In the world emission ranking, China as a country has occupied the first position which makes it possible for the Chinese to be regarded as the highest contributor of greenhouse gas emissions both in the year 2017 and 2018 respectively. This can be seen from the statistical chart in Figs. 1 and 2.

An aspect of energy use which has not been explored is the indirect and off-site energy use as regards to trade and FDI. Liu et al. (2018) recognized this fact by pointing out that efforts so far have been centered on direct and on-site energy use without much concern to the indirect and off-site energy use as regards to trade. Also, Davis et al. (2013); Weidmann (2013) noted that for the rising world economy, many studies are of the view that energy consumption and pollution emission can be transferred as well as goods and services along the supply chains in cross-boundary commercial activities. Through the involvement of commercial transactions, an area or an industrial segment could purchase high-consuming energy goods from other regions or segments, to avert its immediate energy consumption. From the former research on energy use in the manufacturing areas in China, the volume of subsidiary energy use embedded in local commercial activities alone amounted so much than that of immediate energy use (Feng et al. 2013).

The current paper now shift a bit from direct or indirect energy use to a more interesting and attention-seeking area of energy use—embodied energy. On this background, the embodied energy as a blend of the immediate and non-immediate use of energy has drawn more concern in the research community in the direction of energy evaluation aimed at China (Costanza 1980; Tan et al. 2016; Zhang et al. 2016; Wang 2011). Assessment of the energy blending (embodiment) in China's foreign business portrays blended energy transfer of China has increased greatly with the space of 5 years (Tang et al. 2016). Zhang et al. (2016) have come up with a detailed study on the embodied energy use which has shown the particular area of blended energy shifting motivated by diverse levels of concluding request.

Embodied energy use has been limited only to trade activities within the country without duly paying attention to the offshore economic activities. The full impact of the West's outsourced manufacturing activities to China can be felt from the emissions of the greenhouse gases. Studies have shown that half of the current upsurge of China's $CO_2$ emissions is as a result of the industrial products for other nations (the UK, the USA, and emerging economies) (Duncan Clark 2009). The reason is not far-fetched from the Kyoto resolution about the $CO_2$ emissions. The Kyoto resolution maintained that countries where pollutions are produced are to bear the

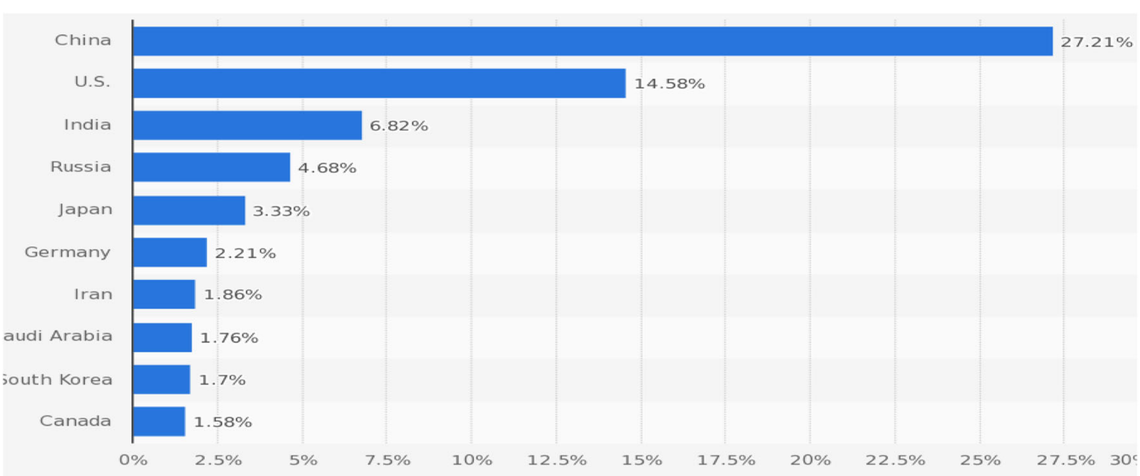


**Fig. 1** 2017 largest producers of fossil fuel, $CO_2$ emissions globally. Source: World Energy Council @ Statista, 2019

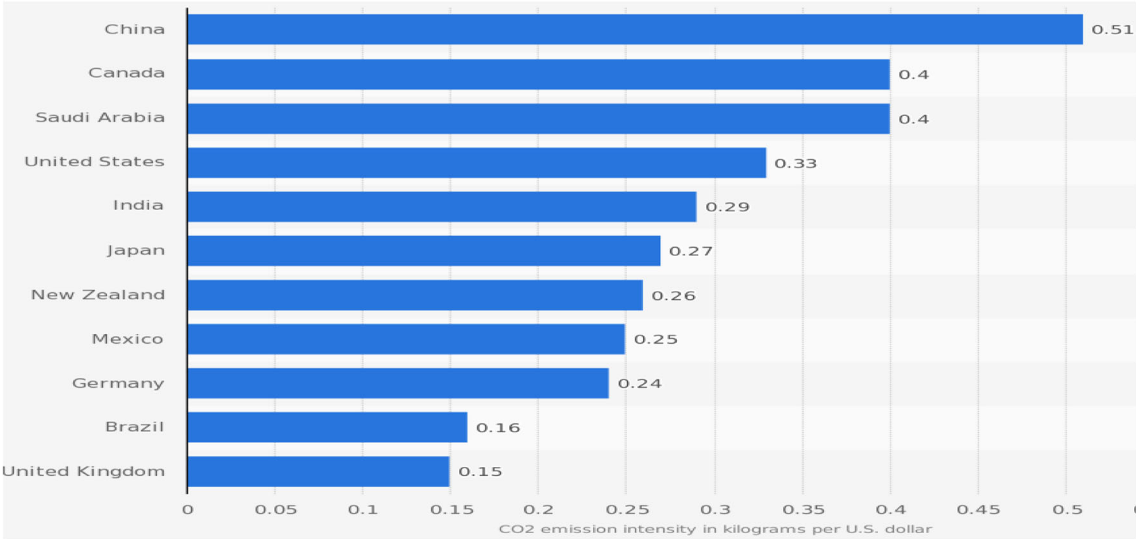


**Fig. 2** 2018 largest producers of fossil fuel, $CO_2$ emissions globally. Source: World Energy Council @ Statista, 2019

responsibility (Duncan Clark 2009). By this rule, developed nations (e.g., the UK, the USA, and other European countries) consider it as an advantage to easily exempt themselves from the $CO_2$ emissions and this informed of their emission reduction to 18% or below which is more sufficient to meet the Kyoto target. Efforts are put in place to make do of less Kyoto's rule but to adopt the resolution of the Copenhagen Summit. The offshore emission is among the key unresolved issues as regards the energy use and $CO_2$ emissions. This has brought the world leaders to breaking of energy use and $CO_2$ emissions into consumption of $CO_2$ emissions and production of $CO_2$ emissions.

To this end, the research seeks to contribute to the current literature by attempting to address the following salient questions while accounting for the effect of environmental degradation: Is there really a correlation between FDI and $CO_2$ emissions through energy use? This has been debated and empirically explored in many works in current literature; nevertheless, findings remain unsettled (Omriand Kahouli 2014; Shahbaz et al. 2015a, b). Is there a transmission between GDP, FDI, and carbon dioxide emission? Is there a connecting factor between GDP and carbon dioxide?

Also, following the contention on who will bear the responsibility of the $CO_2$ emissions of some of the heavily industrialized but developing countries such as China, and considering different views of researchers as regards to the classification of the energy use and $CO_2$ emissions but with little or no insight into the contribution of the offshore economic activities, the present study seeks to investigate and advise on who will bear the responsibility of $CO_2$. With this, the current research bridges the gap by examining the association between FDI and $CO_2$ pollution by integrating the role of monetary development (GDP) for China. This we plan to do by incorporating the foreign direct investment (FDI) and tourism arrivals (TA) to account for the offshore effects. What informs the idea of using FDI in accounting for the offshore activities is that most of the manufacturing and industrial activities are outsourced from one country to another, like the case of China, and most of them come in the form or are regarded as foreign direct investment (FDI). Also, most of the tourist arrivals into a country other than theirs is considered offshore activities and the impact is felt mostly from the energy consumption angle which is utilized in maintaining the tourist sector; this gives rise to high $CO_2$emissions via energy consumption.

The finding in this study confirms that a long-run relationship exists between GDP, tourism arrivals, FDI, energy use, and $CO_2$. Among the findings is that FDI has a positive relationship with both energy use and $CO_2$ and this contributes to $CO_2$ emissions which we classified as the outsourced $CO_2$ emissions in China. As remarked earlier, what informed our claim that this be classified as outsourced $CO_2$ emissions is because of the outsourced economic activities that exist in China through the developed countries like the UK and the USA. Also, the finding from the Granger causality gives credence to our claim that outsourced economic activities are mainly responsible for the high emission in China. Also, we found that tourism arrivals have a positive and significant relationship with energy use and $CO_2$ emissions. Also, we found that both FDI, energy use, $CO_2$, and tourism arrivals have a positive and significant association with GDP which established the triangular nexus causality among the variables and impact on the GDP. This finding affirmed the findings from the studies of Shahbaz et al. (2013) and Aceleanu et al. (2017).

The rest of this research is organized as follows: "Review of related literature" presents the review of literature on the nexus among the choice variables (nexus of GDP and FDI, nexus of FDI and $CO_2$ emissions, and nexus of GDP and $CO_2$ emissions); "Data, methodology, and empirical findings" presents the data, theoretical backgrounds, and methodology and presents the empirical results, interpretations, and discussion; and "Conclusion and policy implications" presents the conclusions and policy implications.

## Review of related literature

The review of previous related literature will be based on comparison and in analysis mediation among the variables. This section is structured to examine the literature by analyzing the relationship between FDI and GDP, FDI and $CO_2$ emission, and $CO_2$ and GDP.

### Nexus between FDI and $CO_2$ emissions

Studies of the association between FDI and the environmental pollution proxy as $CO_2$ has garnered much space and still ongoing. A few of the studies with mixed findings are reviewed here as follows: Pazienza (2015), did a study on OECD countries, considering the relationship between FDI and the environment with a focus on how FDI inflow to the "agriculture and fishing" sector enhance $CO_2$ emission level; his findings shows an adverse connection between FDI and $CO_2$. Blanco et al (2013) deviate from the finding of Pazienza but showed that FDI inflows in pollution-intensive industries can be linked to an increase in environmental degradation via $CO_2$ emissions per capita and per unit of GDP. Shahbaz et al. (2011, 2014), in his panel work on 110 developed and developing countries, found a positive connection between FDI and environmental degradation. This indicates that FDI increases $CO_2$ emissions. Omri et al. (2014) found in his work that FDI arrivals advance the $CO_2$ pollutions by 0.19%. In his work for the developing countries, Talukdar and Meisner (2001) found an adverse significant association between FDI from the developed countries and $CO_2$ emissions. Kheder (2010) observed a positive association among French manufacturing FDI and $CO_2$ pollution in host states. Ben Kheder & Zugravu-Soilita (2008) investigated the association between FDI and the $CO_2$ emissions in China and found a positive connection between FDI and ecological deterioration. Also, Ajide et al (2010) in his work on Nigeria found the positive relationship between FDI (in terms of oil exploration) and $CO_2$ emissions.

### Nexus between GDP and $CO_2$ emissions

Bekun and Agboola (2019) in their work "Electricity Consumption and Economic Growth Nexus: Evidence from Maki Cointegration" found the existence of a long-run equilibrium between real gross domestic product per capita and carbon dioxide emissions. Chen et al. (2016) found in his work for Chinese interregional differences in $CO_2$ emissions that the rate of emitting is different with some at high emissions while some at lower emissions, but majority depicts a positive association between economic growth and $CO_2$ emission. In the work of Balsalobre-Lorente et al. (2018) "How economic growth, renewable electricity and natural resources contribute to $CO_2$ emissions?" they found an N-shaped relationship between economic growth and $CO_2$ emissions. Bekun et al. (2019) in their studies titled "Toward a sustainable environment: Nexus between CO2 emissions, resource rent, renewable and nonrenewable energy in 16-EU countries" found a negative relationship between GDP and $CO_2$ emissions. Balcilar et al. (2019) while working on "Revisiting the economic growth and electricity consumption nexus in Pakistan," they found an equilibrium relationship between economic growth and carbon dioxide emissions. Alola et al. (2019) in their study titled "The role of renewable energy, immigration and real income in environmental sustainability target. Evidence from Europe largest states" found that the nexus of carbon emissions with gross domestic and consumer price is significant, and respectively positive and negative. Akadiri et al. (2019a) did a work on the role of natural gas consumption in Saudi Arabia's output and its implication for trade and environmental quality. Among their findings is that natural gas consumption induces real GDP positively. Twerefou et al. (2016) argued with his findings that per capita income in Ghana has an adverse association with $CO_2$ pollution implying the improved quality of the environment. Lee (2013) found an adverse association between economic advancement (GDP) and $CO_2$emissions in his work on G20 countries. Furthermore, examining the direct effect of economic growth on $CO_2$ pollutions, he established a positive connection between growth and $CO_2$ emissions. Akadiri et al. (2019b) did a work titled "Carbon emissions, energy consumption and economic growth: A causality evidence." Empirical results propose a unidirectional causality running from economic growth to energy consumption and from carbon emissions to energy consumption in the long run. Findings reveal that there is no feedback relationship between economic growth, carbon emissions, and energy consumption of Iraq. Sharma (2011) found a positive influence of economic development on $CO_2$ pollutions. Also, Omotor (2015) confirmed the positive connection between GDP and the environment ($CO_2$) in his work on ECOWAS region. Akadiri et al. (2019) did a work titled "Towards achieving environmental sustainability target in Italy." The role of energy, real income and globalization, and they found that real income has no significant impact on the metric ton per capita of carbon emission level both in the short run and long run. Al-Mulali et al. (2015) in their work titled "Investigating the environmental Kuznets curve hypothesis in Vietnam" found fossil fuel energy consumption increases pollution which impacts the GDP. Sarkodie and Strezov (2019) in their work titled "Effect of foreign direct investments, economic development and energy consumption on greenhouse gas emissions in developing countries" found the validity of the pollution haven hypothesis via the strong positive effect of energy uses on greenhouse gas emissions. Boopen et al. (2011) established an adverse connection between GDP and the environment positing his findings to the increasing rate of human activities. Meanwhile, Acharya (2009) is of the view that FDI has a positive effect on the $CO_2$ discharges through output growth, in other words, he opined that there is a progressive connection between GDP and $CO_2$ pollutions. Apergis and Payne (2009) in their work titled "CO2 emissions, energy usage, and output in Central America" found that real output exhibits the inverted U-shaped pattern related with the Environmental Kuznets curve (EKC) hypothesis.

### Nexus between GDP and FDI

Here, the present study explores some works on causality or relationship between FDI and GDP growth. Paramati et al. (2017) in their studies which is titled "Financing clean energy projects through domestic and foreign capital: The role of political cooperation among the EU, the G20 and OECD countries" found FDI impacting energy use positively thereby impacting the GDP favorably. Xing (2010) found that FDI improves the efficiency of the Chinese domestic economy through intensified competition between the state-owned enterprises and foreign-invested firms in China. Hoang et al. (2010) are of opinion that FDI can only impact the level of income through its contribution to capital accumulation without impacting the long-run growth rate. Hansen and Rand (2006) found strong transmission link between GDP and FDI in their investigation of 31 emerging states for the duration of 1970 to 2000. Anyanwu (2012) found that among the drivers of FDI is a traceable good robust economic growth rate which he observed in the economy of East and South African regions. (Reyath et al. 2009) studied the Gulf cooperation council and established no connection between FDI and monetary growth (GDP). (Magnus and Fosu 2008) examined the Ghanian economy and noticed there is no causation between FDI and GDP. On the same note, Karimi and Yusop (2009) did a work on the Malaysian economy and their finding shows no causation between FDI and economic development. Also, Irandoust (2001) did a work on FDI and growth and found no causality between them. Chakraborty and Basu (2002) explored the causation between FDI and GDP with the Granger causality test and establish a unidirectional connection between FDI and economic advancement. Irandoust (2001) utilized Toda and Yamamoto to test a Granger causation relationship between economic growth and FDI on Scandinavian countries (Denmark, Norway, Finland, and Sweden); they found a two-way transmission among the variables in Sweden and a one-way transmission from FDI to GDP for Norway but no causality relationship for Denmark and Finland.

## Data, methodology, and empirical findings

### Data

This study employed the converted annual to quarterly data of China for the period of 1995Q1–2016Q4. The current work used the quadratic match-sum technique to convert annual frequency data into quarter frequency data. It is established and validated that the outcomes of the annual series method are unresponsive from those of the quadratic match-sum technique (Shahbaz et al. 2017; Romero et al. 2005; Emir and Bekun 2018). The variables used in the current research are international tourism (figure of arrivals), gross domestic product (GDP) constant 2010 US$, $CO_2$ emissions from solid fuel consumption (kt), foreign direct investment net inflows (FDI), and energy use (kg of oil equivalent per capita). All the variables are combed from the Lange et al. (2018) and are all expressed in logarithmic form.

### Theoretical background and model specification

The current work constructs a hypothetical model to investigate the relationship between carbon dioxide ($CO_2$), energy consumption, offshore intensity activities, and economic growth. In order to be more direct to our claim, the study adopted Ehrlich and Holdren's (1972) IPAT model. Following the IPAT framework, the per capita environment is determined by technology and income per capita. The fundamental framework is expressed as follows:

$$y_{1t} = f_2(A_{1t}, T_{1t}) \tag{1}$$

where $y_{1t}$=$l_{1t}/P_{1t}$, and $y_{1t}$ is the per capita $CO_2$ emissions effect. $A_{1t}$ represents wealth, and is calculated by gross domestic product (GDP) per capita; $T_{1t}$ represents technology.

Though technology is difficult to calculate precisely, former works (e.g., Javorick and Spatareanu 2008; Keller 2004) pointed out that increasing FDI impacts technology through spillover effects from investment wealth. Also, Hübler and Keller 2010, bstudied the current literature and found that more effective technologies of external industries can equally add to an energy-subsiding method effect via skill knowledge transfer. To this, the level of tech can be negating or captured by the foreign direct investment (FDI) and substituted by FDI. A few works have investigated the influence of FDI or have used it as a significant cause of environmental quality (Shahbaz et al. 2014; Pazienza 2015; Omri et al. 2014;

Talukdar and Meisner 2001; Kheder et al. 2010; Ajide et al. 2010).

The deviation from the traditional Kuznets curve (EKC) theory (in which increasing decreasing relationship between GDP and environmental quality are measured) shows that it can be analyzed empirically applying diverse procedures of ecological qualities, for instance in the works of Musolesi et al. (2010) who used the traditional EKC to study local pollutant emissions and global pollutant emissions. Also, Galli 1998; Hübler and Keller 2010, b; Sadorsky 2011 apply the EKC in testing energy intensity. Moving a bit further from an old style of the EKC model, where GDP remains the single controlled variable, Selden and Song (1994) revealed that the initial and higher terms of GDP per capita are insignificant. Earlier works that have applied the EKC model failed to recognize the problem where the order one I (1) of the square of an integrated process is having a unit root (Cheng 2014). Wagner (2008) argued that presently, there is no assessment methods for pools as well as nonlinear transformations of the unified process are in place. Hence, it is wrong for the model to add income per capita and its multiplied term when the income is an integrated process. Following the view of Wagner (2008) that at maximum, one of income and its multiplied form can be a unified process (i.e., when income is in the unified process) the current work failed to include the unified form of income (GDP) but rather interchange the position of the $CO_2$ emissions per capita effect with income (GDP per capita). This we undertake in order to research on the vigorous interaction between carbon dioxide ($CO_2$ ) pollution, growth (GDP), energy use, tourism arrivals, and foreign direct investment (FDI), and also bearing in mind the model specification which has GDP per capita as our explained factor. The specification will aid in measuring both the connection of economic growth and the $CO_2$ pollution/emissions, and also the nexus connections between economic growth (GDP), $CO_2$ emissions, FDI, TA, and energy use. This will aid the author to justify the above-raised questions (Is there really an association between FDI and carbon emissions through energy consumption? Is there a transmission among the GDP, FDI and carbon dioxide emission? Is there a connecting factor between GDP and carbon dioxide?)

The model is specified as follows:

$$y_{1t} = f_2(CO_{21t}, FDI_{1t}, TA_{1t}, EU_{1t}) \quad (2)$$

where $y_{1t}$ *is* measured by GDP per capita of the Chinese economy, $CO_{21t}$ denotes carbon dioxide($CO_2$) emission, TA denotes tourism arrival, FDI denotes foreign direct investment which captures the technology effect and reflects the offshore manufacturing activities that give rise to high energy consumption and high emissions of $CO_2$, as cited in "Introduction." According to Glen Peters (2009), some major percentage of Chinese total ($CO_2$) emissions are the outcome of manufacturing industrial products for the USA, and other remaining percentages are from manufacturing industrial products for Europe, and EU denotes energy use.

We employ natural logarithms and a stochastic disturbance term (∈t) in order to show an easy identifiable empirical model and to reflect the concise nature of the data. The effect of offshore activities and the high energy consumption on $CO_2$ emissions can be expressed as:

$$\mathrm{GDP} = \mathrm{C} + B_1 + B_2 CO_2 B_3 + \mathrm{FDI} + B_4 \mathrm{TA} + B_5 \mathrm{EU} + \in t \quad (3)$$

where GDP denotes log of GDP, $CO_2$ represents log of carbon dioxide emission, FDI denotes log of FDI, TA reps log of tourism arrival, EU reps log of energy use and∈t is the error term. $B_{1,}B_2$, $B_3$, $B_4 and$ $B_5$ are the coefficients respectively. $B_2$is the level of impact of $CO_2$ emissions to the income( GDP), and shows the variation in GDP for additional unit variation in $CO_2$ emissions. The GDP in the Eq. (3) shows the association between GDP and $CO_2$emissions, and reveals the growing or declining effect of $CO_2$ emissions on GDP, controlling for other variables; $B_3$ is the level of impact of FDI to the GDP which shows the variation in GDP for additional unit variation in FDI, while $B_4$ and $B_5$show the variation in GDP for additional unit variation in tourism arrival (TA) and energy use (EU) respectively

## Unit root test

Because of the prevalence of the breaks and shocks in the political and economic occurrences in most economies, time series data are always considered not stationary. For this, the time series examination demands the ascertaining of the non-unit root of the variables applied in the research to avoid wrong estimations and falsified results from such analysis. Before the consideration of the model in this study, the stationarity and integrated order of the variables have been checked. We employed and combined different techniques such as Augmented Dickey-Fuller (ADF) (Dickey and Fuller 1981), Phillips-Perron (PP) (Campbell and Perron 1991), and Syczewska (2010) unit root checks to determine if the variables have non-unit root. Table 1 explicitly indicate a mixture of integrating order of the variables at I (0) and I (1).

## ARDL-bound testing approach

For proper model specification and to reduce the likelihood of arriving at misleading or spurious results and analyses, we consider the ARDL approach more suitable for our estimation following the output of the unit root test from different techniques for a robust check. Following Pesaran et al. (2001), we

**Table 1** The results of the unit root tests

| Variables | ADF | PP | KPSS |
|---|---|---|---|
| Unit root test at level | | | |
| LGDP | − 2.004 | 7.774*** | 1.1837*** |
| LTA | − 1.623 | − 1.171 | 1.1583*** |
| LFDI | − 1.625 | − 1.555* | 0.8085*** |
| EU | − 3.126 | − 2.201 | 1.1772*** |
| L $CO_2$ | − 2.924 | 3.523** | 1.1362*** |
| Unit root test at 1st diff | | | |
| LGDP | − 2.3843** | − 2.895 | 1.1418*** |
| LTA | − 3.0317** | − 4.0396** | 0.2212 |
| LFDI | − 2.4391** | − 4.1280 | 0.1232 |
| EU | − 3.2836** | − 3.5333** | 0.1149 |
| L $CO_2$ | − 1.0740 | − 1.0949 | 0.3801** |

*, **, ***Statistical rejection of the null hypothesis at the 1%, 5%, and 10% respectively

considered ARDL a suitable technique for this analysis with the presence of the mixture of order of integration from the unit root test.

## ARDL specifications

The econometric specification of ARDL can be written as follows:

$$Y = C + B_1 + B_2\ CO_2 + B_3 + FDI + B_4 TA + B_5 EU + \in t \quad (4)$$

where $Y$ reps log of GDP, $CO_2$ reps log of carbon dioxide emission, FDI reps log of foreign direct investment (FDI), TA reps log of tourism arrival, EU reps log of energy use, and ∈t reps the error term. $B_1, B_2$, $B_3$ *and* $B_4$ are the coefficients respectively. Further expression and specification of the ARDL is the expansion of the model into ARDL long-run and short-run models. The two models take into considerations the relationship that exists from the GDP to tourism arrivals, FDI, energy use, and $CO_2$ emissions in two separate equations, Eqs. (2) and (3); thus,

$$Y_t = C + B_1 y_{t-1} + B_2 CO_{2t-1} + B_3 FDI_{t-1} + B_4 TA_{t-1} + B_5 EU_{t-1} + \in t \quad (5)$$

$$Y_t = C + a_1 \sum_{i=1}^{n} \Delta y_{t-1}\ a_j \sum_{j=1}^{n} \Delta CO_{2t-j} + a_k \sum_{k=1}^{n} \Delta FDI_{t-1} + a_l \sum_{l=1}^{n} \Delta TA_{t-l} + a_m \sum_{m=1}^{n} \Delta EUP_{t-m} + ECM_{t-1} + \in t \quad (6)$$

where the parameters in Eq. (2); $B_1, B_2$, $B_3$, $B_4$and $B_5$ are long-run coefficients, while in Eq. (3), $a_1, a_j$, $a_k$, $a_l$, and $a_m$are the short-run coefficients. Δ and $ECM_{t-1}$ represent the first difference of variables and the speed of adjustment over the long run respectively. We further expand the ARDL analysis by checking the long-run relationship between the underlying variables using the bound testing approach. We determine the long run by comparing the lower 1(0) and upper 1(1) boundaries with $F$ and $t$ statistics. If the $F$ or $t$ statistics is greater than the lower and upper boundaries, it shows the presence of a long-run relationship and vice versa. We specify the long-run restriction approach of Eq. (2) to capture the interactions among the variables. Thus,

**Table 2** ARDL dynamic estimate of the GDP equation

| Variables | Coefficients | SE | $t$ statistics | Prob |
|---|---|---|---|---|
| Short run | | | | |
| D (LGDP(-1)) | 0.6276*** | 0.0866 | 7.2487 | 0.0000 |
| D(LTA) | 0.6810** | 0.3330 | 2.0636 | 0.0154 |
| D(LFDI) | 0.007100*** | 0.0000003 | 23.333 | 0.0000 |
| COINTEq(-1) | − 0.001820*** | 0.000427 | − 4.265082 | 0.0001 |
| Long run | | | | |
| LTA | 0.3696** | 0.1602 | 2.3071 | 0.0243 |
| LFDI | 0.0071*** | 0.0000004 | 3.22 | 0.0020 |
| EU | 1.5300 | 1.0000 | 1.5224 | 0.1328 |
| L $CO_2$ | 0.0055 | 0.552 | 0.2492 | 0.8039 |
| C | − 1.6100 | 1.3300 | − 1.2055 | 0.2324 |
| Bound test(long run) | | | | |
| $F$ statistics | = 6.54***, $K$ = 4 | 1% | 1(0) bound = 3.74 | 1(1) bound = 5.06 |
| Wald test (short run) | | | | |
| $F$ statistic | 77.1 | | | |
| $P$ value | 0.0000 | | | |

*, **, ***Rejection of the null hypothesis at the 1%, 5%, and 10% respectively. Source: author's computation

$$gdp_t = B_0 + \Sigma\delta B_1 gdp_{t-1} + \Sigma\delta B_2 CO_{2t-1} + \Sigma\delta B_3 fdi_{t-1}\Sigma\delta B_4 ta_{t-1} + \Sigma\delta B_4 ta_{t-1} + \Sigma\delta B_5 eu_{t-1} + B_6 ec_t \varepsilon_{1t} \quad (5.1)$$

The ARDL estimation for both the long run and short run is displayed in Table 2, with optimum lag as indicated by AIC. The cointegration equation for this work exposes .002% speed of adjustment to the equilibrium path on GDP via the impact of tourism arrival (TA), FDI, energy use (EU), and $CO_2$ on a quarterly basis. The result confirms the positive significant association between economic growth (GDP) and the variables tourism arrival and FDI in the short run, and tourism arrival, FDI, energy use, and $CO_2$ in the long run. This means that GDP is impacted positively by both tourism arrival and FDI positively in the short run and long run. This not surprising especially from the angle of FDI considering the rate of outsourced manufacturing and economic activities from some developing nations (e.g., the UK and the USA) into China's economy. This result shows the long run (elasticity) of GDP in terms of $CO_2$ emissions, FDI, tourism arrivals, and energy use are significantly positive. That is to say a 1% rise in $CO_2$ emissions upsurges GDP by 0.005%. A 1% rise in FDI also increases the economic growth (GDP) by 0.007%; likewise, the 1% increase in both tourism arrivals (TA) and energy use (EU) will lead to 0.369% and 1.53% respectively. Supposedly, from our findings, a good economic performance synonymously economic growth is attributed to the ability of China to attract FDI and tourism arrivals as they are significantly and positively impacting the economic growth of China. Over a decade now, there has been a glaring tremendous rise in Chinese FDI and inbound tourism. Also, this translates to the FDI flow into China's economy via an outsourced mode from other countries that impact the tourism sectors which will lead to an expansion in the economic activities. This is in line with the take of Shahbaz et al. (2017) who maintained that the tourism sector can stimulate investments, technological progress, and increase in human capital capacities of nations. Also, we found a positive association between GDP, energy use, and $CO_2$; This implies that over a period of time, say in the long term, a rise in the GDP upsurges the energy use and this consequently increases $CO_2$ emissions. This is in consonance with the findings of Fei et al. (2011). The outcome of this result supports the views of Huanying Cui (2016) which shows that China still advances economic growth at the expense of high energy use and drastic environmental degradations.

**Table 3** Pairwise Granger causality test (short-run causality test result)

| Null hypothesis | *F* stat | *P* value | Causality | Direction |
|---|---|---|---|---|
| LTA→LGDP | 3.1948 | 0.0461** | YES | UNI-DIRECTION |
| LGDP→LTA | 1.4402 | 0.2428 | | |
| LFDI→LGDP | 0.7081 | 0.4956 | YES | UNI-DIRECTION |
| LGDP→LFDI | 8.0868 | 0.0006*** | | |
| LEU→LGDP | 2.9883 | 0.0568* | YES | UNI-DIRECTION |
| LGDP→LEU | 0.7908 | 0.4575 | | |
| L $CO_2$→ LGDP | 1.5254 | 0.2247 | YES | UNI-DIRECTION |
| LGDP→ L $CO_2$ | 3.2338 | 0.0452** | | |
| LFDI→LTA | 1.0532 | 0.3535 | NO | NEUTRAL |
| LTA→LFDI | 1.9233 | 0.1527 | | |
| LEU→LTA | 4.03146 | 0.0220** | YES | BI-DIRECTION |
| LTA→LEU | 2.91019 | 0.0611* | | |
| L $CO_2$→LTA | 1.4804 | 0.2346 | YES | UNI-DIRECTION |
| LTA→L $CO_2$ | 3.1325 | 0.0498** | | |
| LEU→LFDI | 3.13392 | 0.0497** | YES | BI-DIRECTION |
| LFDI→LEU | 3.82685 | 0.0265** | | |
| L $CO_2$→LFDI | 2.3789 | 0.1001 | NO | NEUTRAL |
| LFDI→L $CO_2$ | 1.9036 | 0.1567 | | |
| L $CO_2$→ LEU | 0.4502 | 0.6394 | YES | UNI-DIRECTION |
| LEU → L $CO_2$ | 5.2283 | 0.0077*** | | |

*, **, ***Rejection of the null hypothesis at the 1%, 5%, and 10% respectively. Source: author's computation

**Table 4.** Breusch-Godfrey serial correlation LM test

| | | | |
|---|---|---|---|
| *F* statistic | 0.260596 | Prob. *F*(3,61) | 0.8535 |
| Obs**R*-squared | 0.949052 | Prob. chi-square (3) | 0.8136 |

*, **, ***Rejection of the null hypothesis at the 1%, 5%, and 10% respectively. Source: author's computation

## Granger causality

The conventional regression does not portray a clear cut of causation even though the cointegration employed by the authors with the ARDL-bound approach confirmed the presence of causality. This is limited in determining the direction of the causality or transmission. This informed our choice of testing further the causation and the direction of the choice variables with Granger causality. For the consistency in the findings that causality exists among the choice variables (GDP, TA, $CO_2$, EU, and FDI), the authors applied the pairwise Granger causality test which also serves as a robust check to the findings from the error correction estimation. Hence, the pairwise Granger causality test is displayed in Tables 3, 4 and 5.

The result from Table 3 shows the output from the Granger causality estimation. The findings give credence to the findings of the dynamic and the ARDL-bound approach above. According to the result, there is a uni-directional causality passing from tourism to GDP at 5%, from GDP to FDI at 1%, from

**Table 5.** Heteroskedasticity test: Breusch-Pagan-Godfrey

| | | | |
|---|---|---|---|
| *F* statistic | 2.364950 | Prob. *F*(13,59) | 0.0127 |
| Obs**R*-squared | 25.00812 | Prob. chi-square (13) | 0.0230 |
| Scaled explained SS | 21.32524 | Prob. chi-square (13) | 0.0667 |

*, **, ***Rejection of the null hypothesis at the 1%, 5% and 10% respectively. Source: author's computation

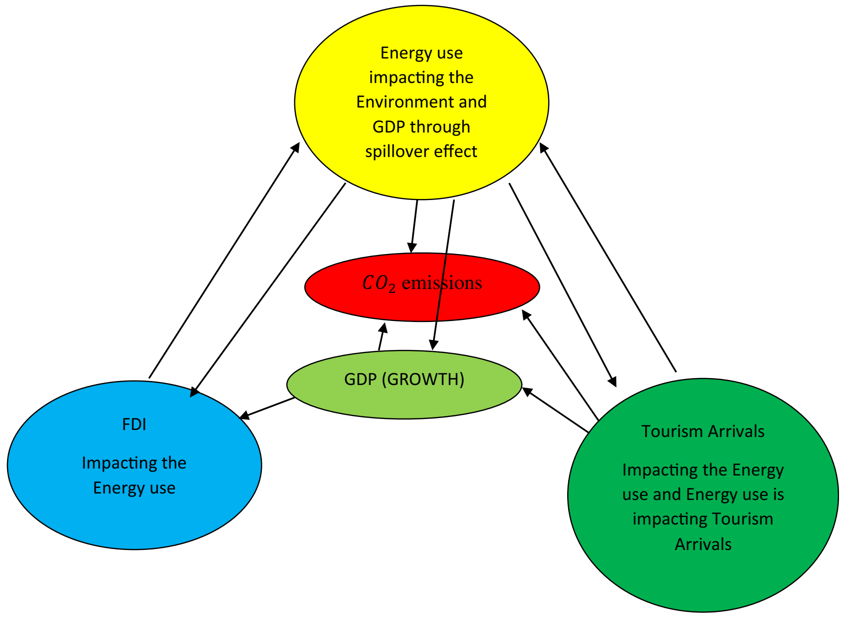


**Fig. 3** Triangular relationship between $CO_2$ emissions, energy use, FDI, tourism arrivals, and growth in the case of China

energy use (EU) to GDP at 10%, from GDP to $CO_2$ at 5%, from tourism arrival to $CO_2$ at 5% and from energy use to $CO_2$ at 1%. This reveals and validates the findings from the ARDL-bound testing that China's economic growth is not far-fetched from energy-induced growth, hence the transmission from energy use to GDP via FDI and tourism maintenance. However, there is a bi-directional causality between energy use and tourism and between energy use and FDI. This shows a trade-off for environmental quality degradation considering the heavy energy consumption emanating from both tourism arrivals maintenance, and FDI activities coming from the industrial and manufacturing activities. The findings are in agreement with other related studies in this area (Shahbaz, Loganathan, Zeshan & Zaman).

The causality is demonstrated in a graphical form (triangular form) as follows:

The arrows are designed in such a way to show the direction of the transmitting. Where one arrow is seen moving from one variable to the other without transmitting back with another arrow, it shows a uni-directional causality, but where there are two arrows moving in opposite direction between two variables (e.g., energy use and FDI and energy use and tourism arrival), it shows a bi-directional causality (Fig. 3).

## Diagnostic test

We further carried a diagnostic test to check if and be sure that our analysis is free from any form of wrong estimation or misspecification which will eventually lead to a spurious result. We checked for the stability and the reliability of the short and long run ARDL model. According to Brown et al. (1975), we employed: (a) cumulative sum (CUSUM) tests and (b) cumulative sum of square test on residuals of the model. The test clearly showed that the stability of the coefficients over the investigated period was ascertained. It is opined that if the

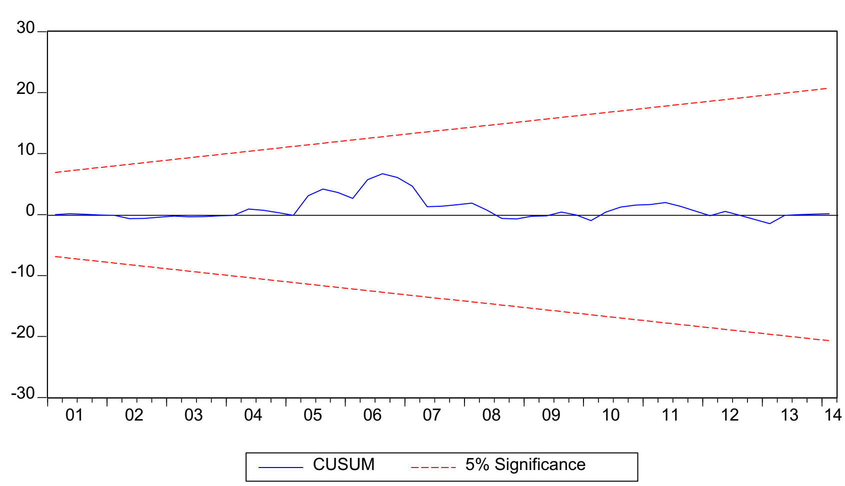


**Fig. 4** Plot of cumulative sum of recursive residuals (the conventional lines denote critical bounds at 5% significance level)

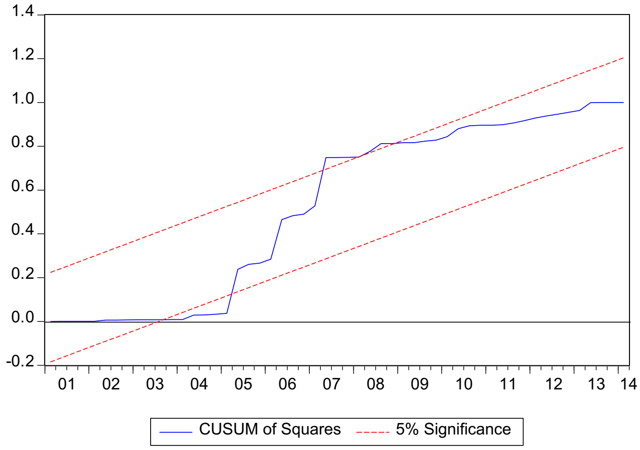


**Fig. 5** Plot of cumulative sum of square of recursive residuals (the conventional lines denote critical bounds at 5% significance level)

plot of the blue line shifts outside the area of the 5% critical line, embodied with a red line, it means that the coefficients are not stable (Oluyombo et al. 2016). Hence, the results obtained in Figs. 4 and 5 show that at the 5% significant level for the applied framework in this work, parameters and variance are stable under both CUSUM and CUSM square tests.

### Serial correlation tests

From the above result of the serial correlation and heteroscedasticity, it is observed that none of the results is significant at 5%; hence, we conclude that the estimations and analyses are stable, justifying the findings from the CUSUM and CUSUMSQ.

## Conclusion and policy implications

The current paper focuses on the mediation among the choice variables of the authors. Emphasis is laid on the triangular nexus among the tourism arrivals (TA), foreign direct investment (FDI) energy use (EU), and ($CO_2$) pollution/emissions which portrays how the interwoven relationship that exit among the chosen variables is tailored towards impacting the economic growth GDP) of China which in turn impact on the environmental quality of the country. The ARDL-bound test confirms that a long run relationship exists between GDP, tourism arrivals, FDI, energy use, and $CO_2$. Among the findings is that FDI have a positive relationship with both energy use and $CO_2$ and this contributes to $CO_2$ emissions which we classified as the outsourced $CO_2$ emissions in China. As remarked earlier, what informed our claim that this be classified as outsourced $CO_2$ emissions is because of the outsourced economic activities that exist in China through the developed countries like the UK and the USA. This finding with Granger causality gives credence to our claim that outsourced economic activities are mainly responsible for the high emission in China. Also, we found that tourism arrivals have a positive and significant relationship with energy use and $CO_2$ emissions. Also, we found that both FDI, energy use, $CO_2$, and tourism arrivals have a positive and significant association with GDP which established the triangular nexus causality between the variables and impact on the GDP. This finding affirmed the findings from the studies of (Shahbaz et al. 2013) and (Aceleanu et al. 2017), where they found positive influence of energy consumption to the economic growth as found in our study. Also, the findings in our study have affirmed the cost implication of heavy energy consumption that is induced from both the outsourced manufacturing activities and the tourism arrivals. This supports the findings of (Saboori and Sulaiman 2013) for Malaysia and (Fei et al. 2011) for China. This is also in agreement with Cui (2016) who opined through his findings that China still advances economic growth at the cost of high energy consumption and drastic environmental degradation.

From the findings of both estimations (dynamic and ARDL-bound test and Granger causality), this study has really provided answers to the questions raised as to what triggered the author's intention of investigating the triangular nexus among the choice variables, thus: Is there really an association between the FDI and $CO_2$ emissions through energy consumption? Is there a transmission between the GDP, FDI, and carbon dioxide emission? Is there a connecting factor between GDP and carbon dioxide?

To this end, the evidence from this result also exposes the components that contribute to $CO_2$ emissions in China, which include GDP growth rate, FDI, tourism activities, and high energy use via the causality output. Therefore, the policy implication should be geared towards implementing the policies and regulations that will checkmate and reduce the excesses of foreign firms to the environment quality of China, and promote environmentally friendly economic activities. Also, the policy implication of China should look into carbon dioxide emissions and shift from a high-carbon economy to a low-carbon economy without much distraction of economy growth. Hence, shifting away from high coal generating energy to renewable energy that is capable of promoting a cleaner system. Also, a concerted effort should be made in moving away from coal to more manageable energy sources (e.g., wind or solar power) in combating high $CO_2$ emissions. Reducing the rate of tropical deforestation and encouraging the manufacture of vehicles with good fuel efficiency, and even switching to solar energy consumption vehicles should be among the policies in consideration. This the country can do by consolidating the FDI and tourism activities and reducing the $CO_2$ emission in sustaining the good performance of the economy via economic growth. Also, looking at the correlation that exists between energy consumption and economic activities, it is no doubt that $CO_2$ emission will definitely follow in the cycle which will be the end product of the whole activity which is also detrimental to the environment. This calls for a watch over the economic and manufacturing activities in the country while considering the policy implication

Conclusively, China should assist in global environmental cooperation and encourage energy saving and climatic change conservation.

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## Compliance with Ethical Standards

**Conflict of interest** The author declares that there are no conflicts of interest.

## References

Aceleanu MI, Şerban AC, Pociovălişteanu DM, Dimian GC (2017) Renewable energy: a way for a sustainable development in Romania. Energy Sources, Part B: Econ, Plann, Policy 12(11): 958–963

Acharya B, Dutta A, Basu P (2009) Chemical-looping gasification of biomass for hydrogen-enriched gas production with in-process carbon dioxide capture. Energy Fuel *23*(10):5077–5083

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

Akadiri SS, Alkawfi MM, Uğural S, Akadiri AC (2019) Towards achieving environmental sustainability target in Italy. The role of energy, real income and globalization. Sci Total Environ:1–13

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

Al-Mulali U, Saboori B, Ozturk I (2015) Investigating the environmental Kuznets curve hypothesis in Vietnam. Energy Policy 76:123–131

Alola AA, Yalçiner K, Alola UV, Saint Akadiri S (2019) The role of renewable energy, immigration and real income in environmental sustainability target. Evidence from Europe largest states. Sci Total Environ:1–15

Anyanwu JC (2012) Why does foreign direct investment go where it Goes?: new evidence from African countries. Annals of Economics & Finance 13(2)

Apergis N, Payne JE (2009) CO2 emissions, energy usage, and output in Central America. Energy Policy 37(8):3282–3286

Balcilar M, Bekun FV, Uzuner G (2019) Revisiting the economic growth and electricity consumption nexus in Pakistan. Environ Sci Pollut Res 26(12):12150–12170

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

Bekun FV, Agboola MO (2019) Electricity consumption and economic growth nexus: evidence from Maki cointegration. Eng Econ 30(1): 14–23

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

Ben Kheder S, Zugravu-Soilita N (2008). The pollution haven hypothesis: a geographic economy model in a comparative study. (view the link for the details https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1266705)

Blanco L, Gonzalez F, Ruiz I (2013) The impact of FDI on CO2 emissions in Latin America. Oxf Dev Stud 41(1):104–121

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

Campbell JY, Perron P (1991) Pitfalls and opportunities: what macroeconomists should know about unit roots. NBER macroeconomics annual, 6, 141–201

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

Chen PY, Chen ST, Hsu CS, Chen CC (2016) Modeling the global relationships among economic growth, energy consumption and CO2 emissions. Renew Sust Energ Rev *65*:420–431

Cheng SC, Wu TP, Lee KC, Chang T (2014) Flexible Fourier unit root test of unemployment for PIIGS countries. Econ Model 36:142–148

Clark D (2009) China's increasing carbon emissions blamed on manufacturing for west. Guardian 23(02)

Costanza R (1980) Embodied energy and economic valuation. Science 210(4475):1219–1224

Cui H (2016) China's economic growth and energy consumption. Int J Energy Econ Policy 6(2):349–355

Davis SJ, Cao L, Caldeira K, Hoffert MI (2013) Rethinking wedges. Environ Res Lett 8(1):011001

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

Ehrlich PR, Holdren JP (1972) Critique. Bull At Sci 28(5):16–27

Emir, F., & Bekun, F. V. (2018). Energy intensity, carbon emissions, renewable energy, and economic growth nexus: new insights from Romania Energy & Environment, 0958305X18793108.

Fei L, Dong S, Xue L, Liang Q, Yang W (2011) Energy consumption-economic growth relationship and carbon dioxide emissions in China. Energy Policy 39(2):568–574

Feng K, Davis SJ, Sun L, Li X, Guan D, Liu W et al (2013) Outsourcing CO2 within China. Proc Natl Acad Sci 110(28):11654–11659

Frimpong JM, Oteng-Abayie EF (2010) When is inflation harmful? Estimating the threshold effect for Ghana. American Journal of Economics and Business Administration 2(3):232

Galli R (1998) The relationship between energy intensity and income levels: forecasting long term energy demand in Asian emerging countries. Energy J:85–105

Hansen H, Rand J (2006) On the causal links between FDI and growth in developing countries. World Economy 29(1):21–41

Hoang TT, Wiboonchutikula P, Tubtimtong B (2010) Does foreign direct investment promote economic growth in Vietnam? ASEAN Econ Bull:295–311

Hübler M, Keller A (2010) Energy savings via FDI? Empirical evidence from developing countries. Environ Dev Econ 15(1):59–80

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

Javorcik BS, Spatareanu M (2008) To share or not to share: does local participation matter for spillovers from foreign direct investment? J Dev Econ 85(1-2):194–217

Karimi, M. S., & Yusop, Z. (2009). FDI and economic growth in Malaysia

Keller W (2004) International technology diffusion. J Econ Lit 42(3): 752–782

Kheder SB (2010) French FDI and pollution emissions: an empirical investigation. University of Paris

Kheder RB, Quere C, Moal J, Robert R (2010) Effect of nutrition on Crassostrea gigas larval development and the evolution of

physiological indices: Part B: Effects of temporary food deprivation. Aquaculture 308(3–4):174–182
Lange GM, Wodon Q, & Carey K (Eds.). (2018) The changing wealth of nations 2018: building a sustainable future. The World Bank
Lee JW, Brahmasrene T (2013) Investigating the influence of tourism on economic growth and carbon emissions: evidence from panel analysis of the European Union. Tour Manag 38:69–76
Liu Q, Wang S, Zhang W, Zhan D, Li J (2018) Does foreign direct investment affect environmental pollution in China's cities? A spatial econometric perspective. Sci Total Environ 613:521–529
MOTOR, O. Sustainability Report (2015)
Musolesi A, Mazzanti M, Zoboli R (2010) A panel data heterogeneous Bayesian estimation of environmental Kuznets curves for CO2 emissions. Appl Econ 42(18):2275–2287
Oluyombo R, Ayodele OE, Akinwusi PO, Okunola OO, Gbadegesin BA, Soje MO, Akinsola A (2016) Awareness, knowledge and perception of chronic kidney disease in a rural community of south-West Nigeria. Niger J Clin Pract 19(2):161–169
Omri A, Kahouli B (2014) Causal relationships between energy consumption, foreign direct investment and economic growth: fresh evidence from dynamic simultaneous-equations models. Energy Policy 67:913–922
Omri A, Nguyen DK, Rault C (2014) Causal interactions between CO2 emissions, FDI, and economic growth: evidence from dynamic simultaneous-equation models. Econ Model 42:382–389
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 relationship between CO2 and foreign direct investment in the agriculture and fishing sector of OECD countries: evidence and policy considerations. Int Econ 9(1):55–66
Pesaran MH, Shin Y, Smith RJ (2001) Bounds testing approaches to the analysis of level relationships. J Appl Econ 16(3):289–326
Sadorsky P (2011) Financial development and energy consumption in Central and Eastern European frontier economies. Energy Policy 39(2):999–1006
Reyath Y, Faras & Khalifa H Ghali 2009,= Toone, J. E. (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.(cross reference)
Romero R, Rocha C, Mantovani JRS, Sanchez IG (2005) Constructive heuristic algorithm for the DC model in network transmission expansion planning. IEE Proceedings-Generation, Transmission and Distribution 152(2):277–282
Saboori B, Sulaiman J (2013) Environmental degradation, economic growth and energy consumption:evidence of the environmental Kuznets curve in Malaysia. Energy Policy 60:892–905
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
Selden TM, Song D (1994) Environmental quality and development: is there a Kuznets curve for air pollution emissions? J Environ Econ Manag 27(2):147–162
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, Khan S, Tahir MI (2013) The dynamic links between energy consumption, economic growth, financial development and trade in China: fresh evidence from multivariate framework analysis. Energy Econ 40:8–21
Shahbaz M, Sbia R, Hamdi H, Ozturk I (2014) Economic growth, electricity consumption, urbanization and environmental degradation relationship in United Arab Emirates. Ecol Indic 45:622–631
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, Chaudhary AR, Ozturk I (2017) Does urbanization cause increasing energy demand in Pakistan? Empirical evidence from STIRPAT model. *Energy 122*:83–93
Sharma RC (2011) Ride analysis of an Indian railway coach using Lagrangian dynamics. Int J Vehicle Structures & Systems 3(4): 219–224
Sy A, Tinker T, Derbali A, Jamel L (2016) Economic growth, financial development, trade openness, and CO2 emissions in European countries. African J Account, Audit Financ 5(2):155–179
Syczewska EM (2010). Empirical power of the Kwiatkowski-Phillips-Schmidt-Shin test (No. 45)
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
Tamazian A, Rao BB (2010) Do economic, financial and institutional developments matter for environmental degradation? Evidence from transitional economies. Energy Econ 32(1):137–145
Tan X, Dong L, Chen D, Gu B, Zeng Y (2016) China's regional CO2 emissions reduction potential: a study of Chongqing city. Appl Energy 162:1345–1354
Tang L, Shi J, Bao Q (2016) Designing an emissions trading scheme for China with a dynamic computable general equilibrium model. Energy Policy 97:507–520
Tully DC, Hjerrild S, Leutscher PD, Renvillard SG, Ogilvie CB, Bean DJ et al (2016) Deep sequencing of hepatitis C virus reveals genetic compartmentalization in cerebrospinal fluid from cognitively impaired patients. Liver Int 36(10):1418–1424
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 Socioecon Stud 4(4):1–12
Uchiyama, S., Kawamoto, K., Gota, C., Yoshihara, T., Tobita, S., Remón, P., & Pischel, U. (2016) An environment-sensitive fluorophore methoxybenzocoumarin emitting in protic environments
Wagner J (2008) Exports, imports, and productivity at the firm level. An international perspective: introduction by guest editor. Rev World Econ 144(4):591–595
Wang Q, Cui Q, Zhou D, Wang S (2011) Marginal abatement costs of carbon dioxide in China: a nonparametric analysis. Energy Procedia 5:2316–2320
Weidmann, N.O. (2013). Transformation strategies towards a sustainable Swiss energy system: An energy-economic scenario analysis (Doctoral dissertation, ETH Zurich)
Wu XF, Chen GQ (2017) Energy use by Chinese economy: a systems cross-scale input-output analysis. Energy Policy 108:81–90
Xing Y (2010) Facts about and impacts of FDI on China and the world economy. China: An International Journal 8(02):309–327
Zhang J, Terrones M, Park CR, Mukherjee R, Monthioux M, Koratkar N et al (2016) Carbon science in 2016: status, challenges and perspectives. Carbon 98(70):708–732
Zhang, W. B. (2018). Economic growth theory: capital, knowledge, and economic structures. Routledge.

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