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RESEARCH ARTICLE

Nexus of ecological footprint and foreign direct investment pattern in carbon neutrality: new insight for United Arab Emirates (UAE)

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Abstract

Carbon neutral is among the possible ways of solving the problem of climate change. Many scholars have utilized different single indicators such as CO_2 and methane with different variables to mitigate the possible ways of solving the problem of global warming. The present study employs a specific country (UAE) approach to investigate the possible way of solving climate change. The author utilized 1980–2018 annual data of the UAE to investigate the possibility of carbon neutral in the UAE as to suggest ways of limiting climate change. Both linear and non-linear (squared) foreign direct investment (FDI) and GDP per capita were added to the study and considered as the variables of interest and other control variables (energy use and population). Among the findings of this study are inverted *U*-shaped relationship between economic growth (GDP per capita) and ecological footprint which confirms EKC for the UAE, positive relationship between energy use and ecological footprint, negative relationship between FDI and ecological footprint in all stages which established a flat pattern of relationship, and a positive relationship between the population and ecological footprint. Findings from causal analyses exposed a two-way direction or feedback (bidirectional) between economic growth (GDP) and urban population, and between energy use and urban population both in the short and long run. Also, a one-way transmission (unidirectional) is found transmitting from ecological footprint and FDI to population both in the short run and long run; from the ecological footprint, energy use, and FDI to economic growth; from the ecological footprint and FDI to energy use in the long run; and from ecological footprint to FDI and energy use in the short run. The policy focus should be towards the improvement on the urban population. FDI pattern suggests the pollution halo hypothesis which is a pointer towards its (FDI) crucial contribution to environmental performance. Hence, FDI should be encouraged through relaxing of some laws that are preventive in nature towards FDI so as to maintain this positive trend towards sustainable development.

Keywords Ecological footprint · GDP · FDI · EKC · PHH · Sustainability · UAE

JEL classification Q00 · Q01 · Q4 · Q43 · Q47 · Q5 · Q56 · Q57 · Q58

Background

The climate issue is a global concern that have triggered actions both at the global level and at the country-specific level towards remedying the problem. Many researchers have embarked on different levels of research with different approaches towards proffering solutions to this global phenomenon. Different indicators ranging from carbon emission, greenhouse gas, methane, and other pollutant indices have been applied in researching this phenomenon with a view on how to remedy the problem of climate change. Research and attempt to possible ways of addressing this global climate concern are still opened. Many factors and activities are responsible for climate change such as unabsorbed excess emitted carbon dioxide. Carbon emission occurs through industrial and agricultural processes such as production activities with heavy types of machinery that emit carbon monoxide and transportation of the product to the final consumers, and this involves emitting of harmful gasses through the exhaust, deforestations through land reclaiming, building of houses, and

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construction of roads. The economic activities in many countries characterized with excessive industrialization principles are geared towards heavy utilization of fossil fuels which most times induce high emissions. Carbon footprint (*the amount of CO_2 injects into the environment due to the activities of people and industries*) has been applied in researching the environmental performance with a considerable amount of findings as regards to causes. However, measuring environmental performance requires a holistic measurement, and this has given rise to some scholars considering ecological footprint as a better indicator for measuring environmental performance, see Fig. 2. As put by the Network (2018), ecological footprints are the human pressure or activities calculated in terms of occupied land and water needed for the production of goods for consumption and the assimilation of the waste in the area. This means the increasing activities of the human and other occupants of the geographical area (simply put, population) that are impacting on the environment which are capable of degrading the quality of the environment. The activities of the humans in a given area range from agricultural activities (land reclaiming in form of deforestation, farming, herders, and fishing) to industrial activities. The ecological footprint of the UAE is rated high considering the population increase in the emirate and the urbanization within the cities of Dubai and other emirates. The UAE ecological footprint is grouped according to sectors and the household with the greater population takes the highest ecological footprint. This is shown in Figs. 1 and 2 below with household as the sector with the highest footprint at 57% followed by business and industry at 30% before government at 12%.

Economic growth and development cannot successively be achieved without the aid of industrialization (Gui-Diby and Renard 2015). The industrialization has influenced most of the urbanizations around the globe through the creation of industries and factories in the cities with high reward as wages and salaries. Production and distribution of the products through various means of transportation are all involved in industrialization. These activities involve the utilization of energy and the emission of carbon into the environment. Apart from industrialization, other activities such as agricultural practice like forest reclaiming, ploughing, cropping, fishery, and herders' activities form part of emitting carbon and methane and other harmful gaseous elements in the air thereby degenerating the ecology. Among the catalysts to industrialization is the foreign direct investment (FDI) inflow. FDI is seen as investments made by foreign companies in foreign countries which give them controlling power over the assets and production in those countries (Kaul et al. 2011). In the same regard with industrialization, the contribution of FDI towards economic growth and development cannot be unnoticed. With regard to the positive effects of FDI on the economic growth and development of the developing economies, FDI is viewed and considered among the indicators always

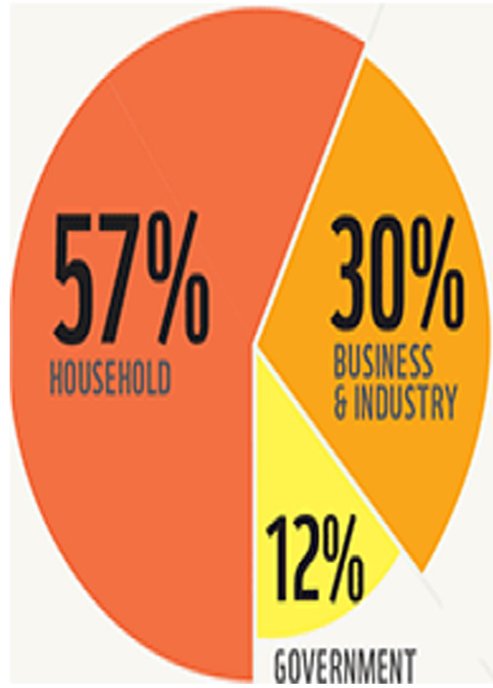


Fig. 1 UAE footprint by demand sector. Source: Global Footprint Network 2019 United Arab Emirates - Global Footprint Network

considered whenever development policies are initiated. FDI positively impacts economic growth and development via pooling of resources, technological advancement and spread over to other domestic industries, improvement of domestic human capitals through capital formation, knowledge and skills transfer, innovative impact through research and development, market location, expansion and international trade integration, and economies of scale (Cipollina et al. 2012; Chen et al. 2015). The industrialization is aided by FDI through the industrial and manufacturing sectors (Klenow and Rodriguez-Clare 1997; Holmes Jr et al. 2016). FDI enhances industrialization through capital and financial resources formation and mobilization, and this is indispensable in the economic growth and development of any serious developing economy (Gui-Diby and Renard 2015; Chen et al. 2015). The overwhelming impacts of FDI are not left without negativity. Some scholars are of opinion that, aside from its many positive impacts towards economic development, FDI still has some negative impact towards the environmental performance of the developing economies (Hassaballa 2013; Shahbaz et al. 2015).

The United Arab Emirates is a country that is characterized by rapid economic growth and development amidst heavy industrialization and foreign direct investment, and it is considered among the most open economies in the Middle East and Arab World. The UAE as a nation comprises seven (7) entities called emirates with each of the entities having its head or ruler. The current population ratio of the UAE in terms of citizens is 80 is to 20. While 80% of the population are

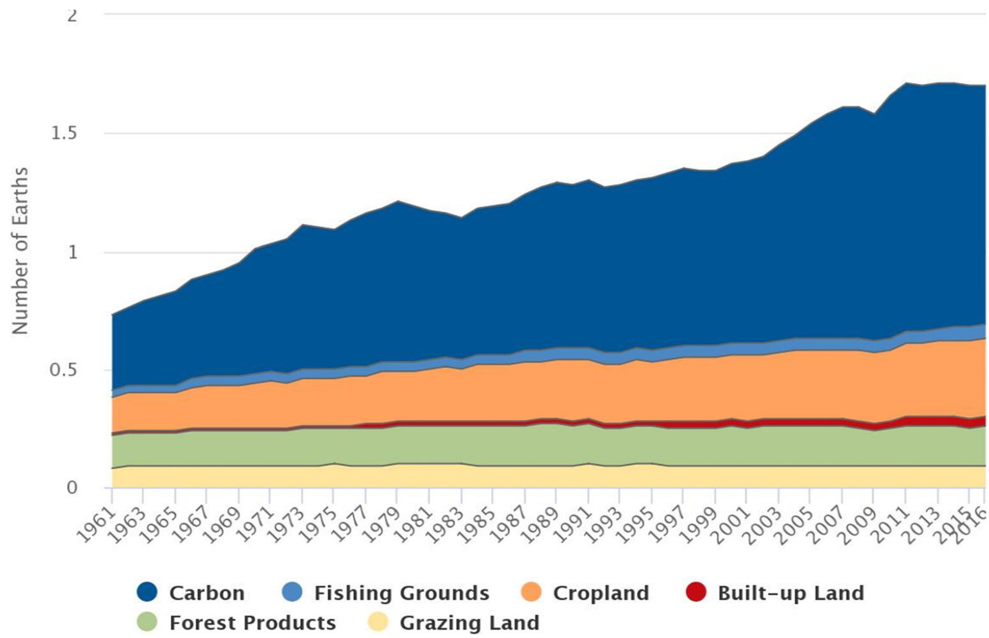


Fig. 2 World ecological footprint by land. Source: Global Footprint Network 2019 National Footprint Account

foreigners, the remaining 20% are UAE citizens. Over 80% of individually owned companies' outputs in the UAE are from non-UAE residents. The country is richly endowed with oil and this made it possible for it to excel through the ladder of development without any hurdle. About 40% of its GDP is generated from oil and gas, and other sectors such as agriculture, service sector, and industrial sector. Most foreign investments in the UAE are spread across these sectors with exemptions of the restricted areas like that of national security and oil sectors. The UAE happens to be among the developing nations that promote FDI for sustainable economic growth and development. Dubai which is among the constituent units of the UAE happens to be the highest and largest recipient of FDI followed by Abu Dhabi. Abu Dhabi is the emirate with over 80% reserve of the UAE oil reserve which promises to host foreign investors with a lucrative idea of resource integration. The quest for attracting FDI for better economic performance is extended to other emirates such as Sharjah, Ras, and Al Kajmah who have equally improved greatly. The UAE happens to be among the least developed countries in the past decades which surmounts the rigorous stages of development to clinch with developed nations (Pauli 2017). With the discovery of oil in the UAE, the country anchored on resource-based industries and FDI promotion approaches to climb through the development ladder. The UAE as a country expands into a business hub of the Middle East and Arab world through tourism and service industries. The country has become a connecting point and investment center for vast investors because of its central position and its non-rigid business policies in most of its sectors for the intending foreign and regional businesses. The UAE has richly harnessed the advantages of foreign direct investment to reform and improve quality of life, and this brings economic growth and development to the country. The UAE is a typical example of a country that justifies FDI's contribution to economic development. The upward trend of foreign direct investment in the UAE picked up after the global economic shock/crises of 2010 to 2013 (Fig. 3), though there was a break in the positive progress (2015 → 2016) but was later picked up and continues till date.

The exploit of the UAE in FDI attraction in their various emirates is not left without limitations. The attraction and influx of FDI into the economies of the emirates are not left unchecked. Even when it appears that the UAE has open and welcoming hands towards foreign investors, there are still some barriers for the investors to gain entrance into the emirates business environment. Some laws and policies pose as deterrents to the potential investors, though the policies (company and Agencies Act) are geared towards the protection of the country's economic growth and to ensure that the benefits of the economic growth are spread to its small citizen base through encouraging its citizens to join the workforce. This makes it hard for foreigners to outrightly own a company without the involvement of UAE citizens at a stipulated percentage, even the restriction to the right to own land with varying degrees of restriction from different emirates and sectors tends to pose a barrier for the potential investors.

United Arab Emirates is richly endowed with oil-related natural resources and it is a known hydrocarbon economy which drives its economic performance on the basis of a resource based (oil and petroleum products). The discovering and the availability of oil resources have structured the economy to function amidst the production and consumption of oil and gas. Currently, the UAE as a member of the Organization

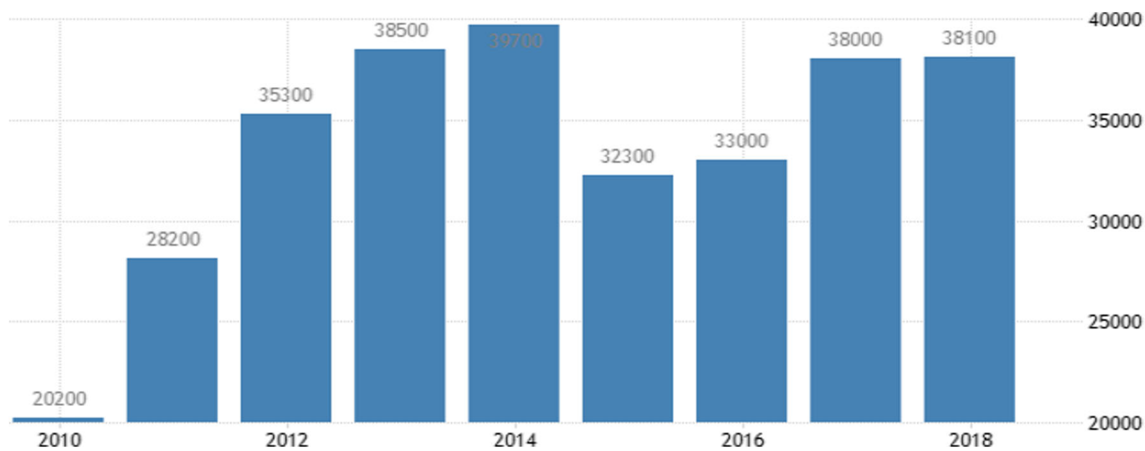
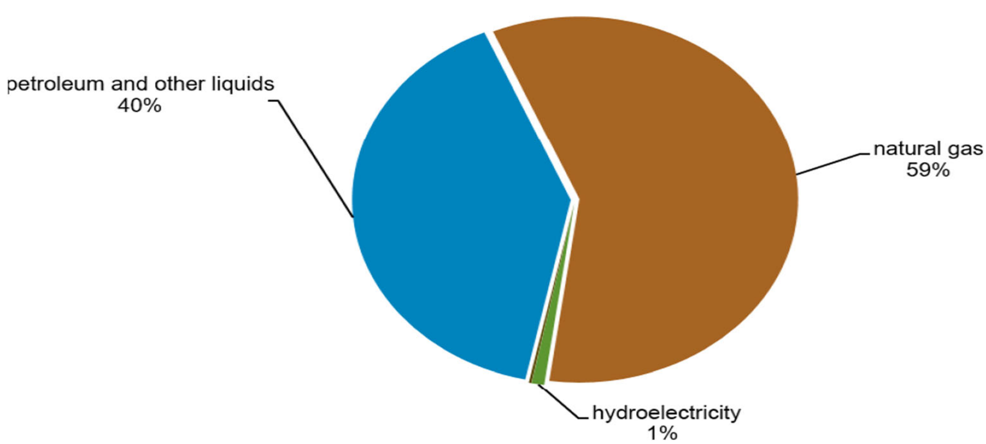


Fig. 3 Foreign direct investment in the United Arab Emirates increased by 38100 AED million in 2018. Source: Tradingeconomics.com/National Bureau of Statistics, UAE

of the Petroleum Exporting Countries (OPEC) is the 7th largest petroleum and other liquids producer in the world. According to the EIA, U. (2018a, b) facts, the UAE boosts its natural gas production to 2.2 trillion cubic feet (TCF) in 2018 (Fig. 5). The upward trend of natural gas production is complemented by the high consumption of gas. In fact, according to the EIA's estimation, 2.7 trillion cubic feet (TCF) was the value of natural gas consumption in the same year 2018. This is a clear pointer that economic growth and development are really straining the UAE's natural gas production and supplies. The extensive utilization of natural gas in the UAE is in the areas of enhanced oil recovery (EOR) operation in its many power plants. The domestic needs and demands of natural gas in the UAE are way higher than the production capacity. This will likely amount to continue importing of large volumes of natural gas to equate to the gas consumption need of the country. The economic development of the UAE which is characterized by heavy industrialization is energy intensive compared with other developing countries. In sum, the UAE's economy is largely fueled by fossil fuel (gas and oil) (Figs. 4 and 5).

The fact that the UAE economic advancement amidst heavy industrialization is highly powered by fossil fuel energy sources is a pointer that the country is a potential carbon emission promoter if not checked. The energy consumption mix as displayed in Fig. 4 portrays the country as one capable of emitting high pollutant emissions. The geographical location and position of the United Arab Emirates (UAE) in a temperate region and hyper-arid environment make climate change a threat to the United Arab Emirates. If not controlled, the impact of climate change will be disastrous to the UAE considering its geographical location. The likely exposed areas the climate variation will affect in UAE are water bodies (coastal, riverine, and marine), dryland ecosystems, agriculture and food security, public health, and construction (buildings and infrastructures). Potential effects of climate change on these areas include extreme hot weather, sea-level rise, storm surge, water stress, dust and sand storms, and desertification. As noted, many researchers have utilized different measures in researching and analyzing environmental degradation in a bid to proffer solutions to climate change and warming. Most times, it is more appropriate to investigate climate change with a comprehensive indicator such as ecological

Fig. 4 Total primary energy consumption in the UAE by fuel, 2018. Source: BP Statistical Review of Energy BP, B. P. 2019



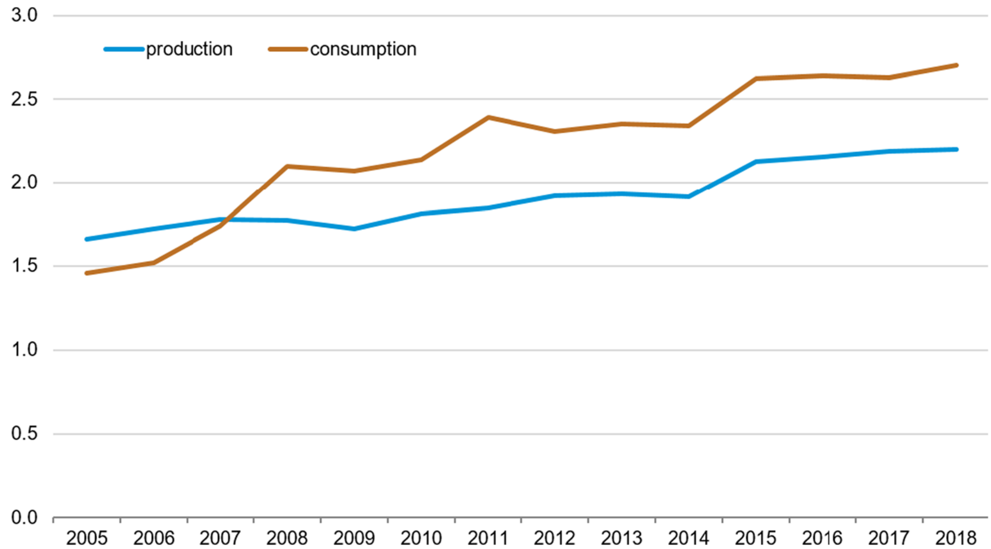


Fig. 5 UAE's dry natural gas production and consumption, 2018 (trillion cubic feet). Source: U.S Energy Information Administration (EIA) EIA, U. 2018a, 2018b

footprint because of the complex nature of the subject. Researchers (Rees 1992; Wackernagel 1994; Wackernagel and Rees 1998; Majeed and Mazhar 2019; Liu and Kim 2018; Ali et al. 2020; Udemba 2020a, b; Destek et al. 2020a, b) have adopted ecological footprint as an indicator to study the environmental dilapidation and climate change. Most of them have adopted other variables like FDI and financial variables to investigate the ecological footprint of the location of their interest. Some have applied panel study in a cross-country study.

Based on the title of this study as it borders on the possibility of carbon neutral in the United Arab Emirates (UAE) and coupled with the upsurge of FDI and heavy industrialization that characterized the economic growth and developments of the country, the present study seeks to investigate the following: (a) possible impact of FDI towards carbon removal and (b) impact of FDI on the environment. This work is not the first to study the impact of FDI on ecology. In fact, many scholars have dealt with this topic in different perspectives. The uniqueness of this present work is the incorporation of the squared term of foreign direct investment (FDI^2) to check the shape of the relationship that exist between FDI and the environment for the case of the UAE. This is formed on the premises of the debate that surrounds the impact of FDI on the environment which necessitated the emerging of the pollution haven/halo hypothesis (PHH). There is no unified form of impact of FDI on the environment. Some findings have uncovered negative relationship (pollution haven hypothesis) while others have uncovered positive effect (pollution halo hypothesis); these variations in findings of previous studies for different economies coupled with the fact that no work has tried to trace the movement or historical pattern of the FDI impact on the environment gives rise to this investigation. To the author's knowledge, no researcher has adopted this approach in examining the relationship that exist between FDI and environmental quality except Charfeddine and Khediri (2016) and Shahbaz et al. (2013a, b). Charfeddine and Khediri tested the inverted *U*-shaped with financial development for the UAE and found an inverted *U*-shaped relationship between financial development and carbon emission for the UAE. Also, Shahbaz and his group applied this in their study for Indonesia to examine the nature of the connection that exist between financial improvement and environmental performance. They found an inverted *U*-shaped relationship for Indonesia. Some developing economies especially the UAE have a progressive and upward trend or pattern of FDI impact on their economic development and this calls for in-depth study of the impact of FDI on both economic performance and environmental performance with attention to the historical pattern of FDI impact on the environment. The ecological footprint is considered a more comprehensive measure of the environment because of its composition of six (6) components that are put together as a single indicator. The author employed some scientific approaches like structural break analysis to make sure that the findings of this study are verified and robust for sustainable policies as regards to economy and environment with a focus on carbon removal.

The remaining part of the present study is patterned as follows: "Theoretical-contextual and related studies"; "Methodology"; "Empirical result and discussion"; "Conclusion and policy implications."

Theoretical-contextual and related studies

This study adopts two notable hypotheses in the field of energy and environmental economics that have been tested by a quite number of studies with divergent findings, environmental Kuznets curve (EKC), and pollution haven hypothesis (PHH).

The EKC was applied by Simeon Kuznets (1955) to test the interaction of economic progression (GDP growth) and income imbalance. He hypothesized a *U*-shaped relation with reference to the widening gap between economic growth and income inequality which the trend is expected to persist to a certain point which is considered a turning point of the curve. The relocation of farmers to the urban cities for a higher paid job plays a major role in a turning point; hence, the farmers who are more of peasant farmers move to the cities for higher paid white-collar jobs. As the farmers relocate to cities and secure white jobs, their per capita income (per capita income of the population) increases thereby closing the gap between economic growth and income inequality. This trend supposed that at the initial stage of the economic growth where the majority of the population are rural farmers, there tends to be a wide gap between the per capita income of the population and the income disparity till a certain point where the majority of farmers moved to the city and are gainfully employed. At this point, the gap between economic growth and income inequality will shrink and continue to reduce till equality is reached (Yandle 2004). Subsequent to the successful establishment of this theory, Grossman and Krueger (1991), Shafik and Bandyopadhyay (1992), and Panayotou (1993, 1997) utilized the EKC hypothesis in testing the association of the GDP performance (income) and environmental well-being. The EKC was adopted and hypothesized a *U*-shaped between economic growth and environmental performance. The hypothesis suggests that as economic growth picks up, the environmental performance suffers to a point of *U*-shaped turn where the furtherance of economic growth paves way for positive environmental performance, and this height of economy is known as industrialized/developed economy. Grossman and Krueger (1991) depicts this trend in three (3) stages: (a) scale effect/stage—the initial stage of economic growth that is characterized by excessive need and use of natural resources which most of them are fossil fuels, waste generation, and catch-up moment in the economic history of most developing nations. The economy tends to grow within the use of fossil fuels at the cost of the atmosphere as much care is given to the economic progression more than the ecology; (b) structural/composite effect—at this stage of economic growth, structural changes set in through the adoption of innovative ways of growing the economy without much negative impact on the environment. This stage is characterized by awareness among the citizenry on the environmental performance of the country because of the pattern of economic growth, and this will lead to a shift to more environmentally friendly practices in the economy. At this stage, innovations and the adoption of new technology will start replacing the old ways of industrial and manufacturing practices in the economy. The degradation of the environment will start reducing because of the structural changes taking place in the economy; (c) technical effect/stage—at this stage, the economy is said to be industrialized/developed. Most of the old ways of industrial practices are altered and new ways are adopted because of the technological advancement via research and development (R&D). People are becoming more inclined to professional services such as medics, engineers, nurses, teachers, and others' welfare and service providers. The masses are enlightened and well informed of the importance of a green (carbon-free) economy which assures a better environmental performance void of pollution. Many scholars have tested this hypothesis and found variant results peculiar to the economies of their targets while researching (Alola et al. 2019; Zafar et al. 2019; Alola 2019a, b; Sharif et al. 2020; Liu et al. 2020; Charfeddine and Khediri 2016; Gill et al. 2018 ; Ozatac et al. 2017; Basarir and Arman 2014; Shahbaz et al. 2013a, b; Shahbaz et al. 2014 ; Ozcan 2013; Sbia et al. 2017; Sarkodie and Ozturk 2020; Shahbaz et al. 2015; Dogan and Ozturk 2017).

The second theoretical background of this study is anchored on the pollution haven hypothesis (PHH). PHH suggests that emerging/developing economics suffer from the activities of the foreign investors who shift the production of pollution-intensive products to their economies mostly because of the relaxed nature of environmental regulation in those economies (Copeland and Taylor 2005; Bommer 1999; Eskeland and Harrison 2003). Aside from the non-existence of stringent policies to check the excess of these foreign investors who transfer their productions into the developing economies, other factors such as availability of market and natural resources in form of raw materials for their production and availability of labor at a cheaper rate are considered in locating and transferring their operations to developing economies (Anyanwu 2012). These factors give the developing economies a comparative advantage over the developed economies in the production of these pollution-intensive products, and this will turn around and affect their environment negatively.

On the contrary basis, Porter and Van der Linde (1995) came up with a positive view in support of FDI which posits that if the awakening of the results of FDI is met with stringent regulation, it will lead to technological innovation that will impact the environment favorably without pollutant emission. But, the challenge is the application of stringent policies by developing economies. As observed by Temurshoev (2006), most times, it is challenging for the developing economies to adopt and implement the environmental laws because of the following reasons: (a) cost implication with regard to formation and implementation of the policies; (b) objective and goal priority—economic growth with attention to increase in per capita income and employment opportunities for the masses is first in priority in goal achievement in most developing nations; (c) most developing economies are more of agrarian and natural resource-based economies. These are among the compelling factors coupled with relatively relaxed laws that pull the potential FDI into the sectors (industrial) that are targeting the natural resources for production. Most of the productions are energy and pollution intensive in nature which impact the environment unfavorably, and this enhances climate change. The comparative implication of FDI is seen from its dual impacts on the developed and developing economies. The FDI impacts positively on the environment of the developed economies because of the strict environmental laws, while it (FDI) performs negatively on the environment of the developing economies because of relaxed laws. The multinational corporations that engage in the production of energy and pollution-intensive products in developing economies perform their productive exercise in a friendly environmental manner according to the stipulated laws in developed economies.

In furtherance of opinions about the impact of FDI, a halo hypothesis (PHH) was conceived by Neumayer (2001). The supporters of the pollution halo hypothesis (PHH) are keys to the opinion that foreign investment has a progressive result on both the economy and the environment. FDI is considered gainful via skill transfer, spillover effects, and economies of scale benefits in the economy. This involves the introduction of superior and advanced machines to the economy that helps in skill transfer, transformation of human capital, and economies of scale and which are less emission intensive (Zarsky 1999). However, Zarsky (1999) and Doytch and Uctum (2011) mirror this view with a direct impact of FDI on the service sector. They are of opinion that the halo hypothesis often holds for the service sector while the haven hypothesis is valid for sectors with dirty production activities such as energy and petroleum, mining, manufacturing, and agricultural sectors. These opinions show that a unified result has not been achieved yet on the effect of FDI on the ecology, hence, leaving the subject open for more investigations. Empirically, a number of studies have been done and found different results for the FDI implication and effect on ecology (Sbia et al. 2014; Agha and Khan 2015; Shahbaz et al. 2018; Abdouli and Hammami 2017; Qasrawi 2004; Abdouli and Hammami 2018; Hakimi and Hamdi 2016; Shahbaz et al. 2015).

Specifically, among the scholars who found a positive impact of FDI on the environment are Hoffmann et al. (2005); Merican et al. (2007); Acharyya (2009); Blanco et al. (2013); Zhang and Zhou (2016); Sapkota and Bastola (2017); Udemba et al. (2019); and Udemba (2020a, b) for India and Nigeria. However, some other scholars found negative interaction between FDI and environment (Al-Mulali and Tang 2013; Neequaye 2015; Tang et al. 2016; Udemba 2019 and Udemba et al. 2020).

Methodology

Model specification, variables, and data

The specification of the current study's model follows the theoretical background of the study and the objective of the study. Thus, the environmental Kuznets curve (EKC) and pollution haven/halo hypothesis (PHH) with the application of squared FDI determine the model specification of the study. First, the EKC theory suggests an inverted *U*-shaped connection among economic performance (GDP) and environmental performance (poor quality or good quality). The PHH postulates the impact of FDI on environmental performance to be negative in developing economies. Also, squared FDI will be incorporated in the model with the expectation of an inverted *U*-shaped relationship between FDI and environment for the case of the UAE. In consideration of the two hypotheses (EKC and PHH), the present study employs the following variables: economic growth, FDI, energy use (consumption), and population as the explanatory variables. Hence, the model specification based on EKC and PHH is specified as the following equation:

$$\mathrm{EFP} = \left(\mathrm{Y},\ \mathrm{Y}^2, \mathrm{EU},\ \mathrm{FDI},\ \mathrm{FDI}^2,\ \mathrm{POP}\right) \tag{1}$$

As specified in Eq. (1), EFP is a biological (ecological) imprint use as an index to account for the ecosystem quality while income (GDP) and income (GDP) squared are represented with Y and Y^2 respectively; EU denotes energy use; FDI and FDI^2 are respectively, foreign direct investment and foreign direct investment squared; POP denotes urban population. Equation (1) is remodeled in an estimable econometric model as following:

$$\mathrm{EFP}_t = \delta_0 + \delta_1 Y_t + \delta_2 {Y_t}^2 + \delta_3 \mathrm{EU}_t + \ \delta_4 \mathrm{FDI}_t + \ \delta_5 {\mathrm{FDI}_t}^2 + \ \delta_6 \mathrm{POP}_t + \varepsilon_t \tag{2}$$

Bearing in mind the objective of testing the EKC and PHH to ascertain if an inverted *U*-shaped relationship exists between the economic growth and environmental performance, and between FDI and environmental performance, the empirical model is anchored on Apergis and Payne (2009); Shahbaz et al. (2013a, b); Apergis and Ozturk (2015); and Charfeddine and Khediri (2016). The model takes the following form as:

$$\mathrm{LEFP}_t = \delta_0 + \delta_1 LY_t + L\delta_2 {Y_t}^2 + \delta_3 \mathrm{LEU}_t + \ \delta_4 \mathrm{FDI}_t + \ \delta_5 {\mathrm{FDI}_t}^2 + \ \delta_6 \mathrm{LPOP}_t + \varepsilon_t \tag{3}$$

The model specification is further expanded for the purpose of cointegration estimates. In the determination of cointegration relationship among the selected variables, the author follows Pesaran and Shin's (1998) and Pesaran et al. (2001) model by utilizing autoregressive distributed lag (ARDL) bounds testing. The model is further extended to the following equations:

$$\begin{aligned}\Delta \mathrm{LEFP}_t = {} & \delta_0 + \delta_1 \mathrm{LEFP}_{t-1} + \delta_2 LY_{t-1} + \delta_3 {LY_{t-1}}^2 \\ & + \delta_4 \mathrm{LEU}_{t-1} + \delta_5 \mathrm{FDI}_{t-1} + \delta_6 {\mathrm{FDI}_{t-1}}^2 \\ & + \delta_7 \mathrm{LPOP}_{t-1} + \textstyle\sum_{i=0}^{s-1} \theta_1 \Delta \mathrm{LEFP}_{t-i} \\ & + \textstyle\sum_{i=0}^{t-1} \theta_2 \Delta LY_{t-i} + \sum_{i=0}^{t-1} \theta_3 \Delta {LY_{t-i}}^2 \\ & + \textstyle\sum_{i=0}^{t-1} \theta_4 \Delta \mathrm{LEU}_{t-i} + \sum_{i=0}^{t-1} \theta_5 \Delta \mathrm{FDI}_{t-i} \\ & + \textstyle\sum_{i=0}^{t-1} \theta_6 \Delta {\mathrm{FDI}_{t-i}}^2 + \sum_{i=0}^{t-1} \theta_7 \Delta \mathrm{LPOP}_{t-i} \\ & + \mathrm{ECM}_{t-i} + \varepsilon_t \end{aligned} \tag{4}$$

$$\begin{aligned}\Delta LY_t = {} & \delta_0 + \delta_1 \mathrm{LEFP}_{t-1} + \delta_2 LY_{t-1} + \delta_3 {LY_{t-1}}^2 \\ & + \delta_4 \mathrm{LEU}_{t-1} + \delta_5 \mathrm{FDI}_{t-1} + \delta_6 {\mathrm{FDI}_{t-1}}^2 \\ & + \delta_7 \mathrm{LPOP}_{t-1} + \textstyle\sum_{i=0}^{s-1} \theta_1 \Delta LY_{t-i} \\ & + \textstyle\sum_{i=0}^{t-1} \theta_2 \Delta \mathrm{LEFP}_{t-i} + \sum_{i=0}^{t-1} \theta_3 \Delta {LY_{t-i}}^2 \\ & + \textstyle\sum_{i=0}^{t-1} \theta_4 \Delta \mathrm{LEU}_{t-i} + \sum_{i=0}^{t-1} \theta_5 \Delta \mathrm{FDI}_{t-i} \\ & + \textstyle\sum_{i=0}^{t-1} \theta_6 \Delta {\mathrm{FDI}_{t-i}}^2 + \sum_{i=0}^{t-1} \theta_7 \Delta \mathrm{LPOP}_{t-i} + \mathrm{ECM}_{t-i} \\ & + \varepsilon_t \end{aligned} \tag{5}$$

$$\begin{aligned}\Delta \mathrm{LEU}_t = {} & \delta_0 + \delta_1 \mathrm{LEFP}_{t-1} + \delta_2 LY_{t-1} + \delta_3 {LY_{t-1}}^2 \\ & + \delta_4 \mathrm{LEU}_{t-1} + \delta_5 \mathrm{FDI}_{t-1} + \delta_6 {\mathrm{FDI}_{t-1}}^2 \\ & + \delta_7 \mathrm{LPOP}_{t-1} + \textstyle\sum_{i=0}^{t-1} \theta_1 \Delta \mathrm{LEU}_{t-i} \\ & + \textstyle\sum_{i=0}^{s-1} \theta_2 \Delta LY_{t-i} + \sum_{i=0}^{t-1} \theta_3 \Delta \mathrm{LEFP}_{t-i} \\ & + \textstyle\sum_{i=0}^{t-1} \theta_4 \Delta {LY_{t-i}}^2 + \sum_{i=0}^{t-1} \theta_5 \Delta \mathrm{FDI}_{t-i} \\ & + \textstyle\sum_{i=0}^{t-1} \theta_6 \Delta {\mathrm{FDI}_{t-i}}^2 + \sum_{i=0}^{t-1} \theta_7 \Delta \mathrm{LPOP}_{t-i} \\ & + \mathrm{ECM}_{t-i} + \varepsilon_t \end{aligned} \tag{6}$$

$$\begin{aligned}\Delta \mathrm{FDI}_t = {} & \delta_0 + \delta_1 \mathrm{LEFP}_{t-1} + \delta_2 LY_{t-1} + \delta_3 {\mathrm{LY}_{t-1}}^2 \\ & + \delta_4 \mathrm{LEU}_{t-1} + \delta_5 \mathrm{FDI}_{t-1} + \delta_6 {\mathrm{FDI}_{t-1}}^2 \\ & + \delta_7 \mathrm{LPOP}_{t-1} + \textstyle\sum_{i=0}^{t-1} \theta_1 \Delta \mathrm{FDI}_{t-i} \\ & + \textstyle\sum_{i=0}^{t-1} \theta_2 \Delta \mathrm{LEU}_{t-i} + \sum_{i=0}^{s-1} \theta_3 \Delta LY_{t-i} \\ & + \textstyle\sum_{i=0}^{t-1} \theta_4 \Delta \mathrm{LEFP}_{t-i} + \sum_{i=0}^{t-1} \theta_5 \Delta {LY_{t-i}}^2 \\ & + \textstyle\sum_{i=0}^{t-1} \theta_6 \Delta {\mathrm{FDI}_{t-i}}^2 + \sum_{i=0}^{t-1} \theta_7 \Delta \mathrm{LPOP}_{t-i} \\ & + \mathrm{ECM}_{t-i} + \varepsilon_t \end{aligned} \tag{7}$$

$$\begin{aligned}\Delta \mathrm{FDI}_t = {} & \delta_0 + \delta_1 \mathrm{LEFP}_{t-1} + \delta_2 LY_{t-1} + \delta_3 {LY_{t-1}}^2 \\ & + \delta_4 \mathrm{LEU}_{t-1} + \delta_5 \mathrm{FDI}_{t-1} + \delta_6 {\mathrm{FDI}_{t-1}}^2 \\ & + \delta_7 \mathrm{LPOP}_{t-1} + \textstyle\sum_{i=0}^{t-1} \theta_1 \Delta \mathrm{LPOP}_{t-i} \\ & + \textstyle\sum_{i=0}^{t-1} \theta_2 \Delta \mathrm{FDI}_{t-i} + \sum_{i=0}^{t-1} \theta_3 \Delta \mathrm{LEU}_{t-i} \\ & + \textstyle\sum_{i=0}^{s-1} \theta_4 \Delta LY_{t-i} + \sum_{i=0}^{t-1} \theta_5 \Delta \mathrm{LEFP}_{t-i} \\ & + \textstyle\sum_{i=0}^{t-1} \theta_6 \Delta {LY_{t-i}}^2 + \sum_{i=0}^{t-1} \theta_7 \Delta {\mathrm{FDI}_{t-i}}^2 + \mathrm{ECM}_{t-i} \\ & + \varepsilon_t \end{aligned} \tag{8}$$

The variables expressed in Eqs. (1) → (3) are FP, Y, Y^2, EU, FDI, and FDI^2, and POP which represent is ecological footprint (constant per capita); GDP and squared GDP (all in constant 2010 US$); energy utilization (million tonnes oil equivalent); foreign direct investment, net inflows and foreign direct investment, net inflows squared (all in % of GDP); and urban population. t represents the sample period which is 1980–2018. ε_t is the error term, and δ_i = (i = 1, 2, 3, 4, 5, and 6) represents the parameters (coefficients) to be estimated. Equations (4) → (8), with the exception of the variables previously defined, depicts the ARDL-bound testing modeling of cointegration relationship (long run) and short run among the chosen variables with error corrections/term (ε_t) and differenced (Δ) form of the variables. ECM_{t-i} represents the swiftness of convergence concluded in a certain period of time regarded as a long period which establishes long path association among the variables. δ_i & θ_I = 1, 2, 3, 4, 5, 6 and 7 represent long-run and short-run coefficients. The cointegration is estimated with ARDL-bound testing on the ground of the null hypothesis advocating for non-cointegration among the variables. The null hypothesis is expressed as $H_0 = \delta_I = 0$ showing no cointegration, while the alternative hypothesis rejects the null hypothesis with $H_1 = \delta_I \neq 0$. The F-statistics and the critical values of both bounds (i.e., upper and lower) are compared for this purpose. Cointegration is upheld if the F-stats is greater than the critical values of bounds (i.e., upper and lower), while the null hypothesis is accepted when the F-stats is less than the critical values of both bounds. The result will be inconclusive if F-stats is in between upper and lower bounds. Except for FDI that is expressed as a percentage (%) of GDP, all other variables are expressed in logarithmic form. Worth noting that energy use is the summation of two dominating fossil fuels in the UAE economy (i.e., oil and natural gas) all measured in million tonnes oil equivalent. The two sources of energy are chosen because of their domineering factor in the energy mix in the UAE economy and availability of data as displayed in Fig. 1. The ecological footprint is the summation of six (6) individual indicators and measured in a global hectare, per capita. There has been contention on the right indicator to measure or proxy environment. Some scholars are more inclined to using CO_2 emission while others consider other single indicators such as methane or nitrous oxide. Though it is quite understandable that some researchers made their choice of variables based on the objectives or perspectives of research, this might not give comprehensive or in-depth knowledge or understanding of the environmental performance. There are different components of emissions that impact the environment which can lead to climate change. As put by (Whittle et al. 2010), the sources of gasses that aid the greenhouse effect that culminates into environmental alteration are CO_2, methane, nitrous oxide, and water vapor. Also, the Intergovernmental Panel on Climate Change (IPCC 2014) quantifies the gasses that cause environmental alteration as follows: CO_2 (76%); methane (16%); nitrous oxide (6.2%). Some other bodies and scholars have equally advocated the potentials of methane and nitrous oxide to contribute towards climate change (Rosenzweig et al. 2018). These are pointers towards the imbalanced nature of using a single indicator to measure the subject environment in studies except where there is a specific objective to achieve. The ecological footprint is considered a more comprehensive measure of the environment because of its composition of six components that are summed up into a single indicator. There are many factors that impact climate change through the deplorable environment, and all these factors are all encompassing in ecological footprint. It is more appropriate to investigate climate change with a comprehensive indicator such as ecological footprint because of the complex nature of the subject (environment). Some other researchers (Rees 1992; Wackernagel 1994; Wackernagel and Rees 1998; Majeed and Mazhar 2019; Liu and Kim 2018; Ali et al. 2020; Udemba 2020a, b; Destek and Okumus 2019; Destek et al. 2020a, b) have equally adopted ecological footprint as an indicator to study the environmental dilapidation and climate change. The economic performance (growth) is measured as income per capita and income per capita squared (all in constant 2010 US$) to show the shape (inverted) of the EKC relationship that exist between economic growth and environment (Kivyiro and Arminen 2014). FDI is measured as foreign direct investment, net inflows and foreign direct investment, net inflows squared (all in % of GDP) in line with the objective of this study to ascertain the historical pattern of FDI impact on the environment, and if inverted shape relationship exists between FDI and environment. The population is measured with the urban population. Apart from energy use and ecological footprint data that are sourced from British Petroleum Petroleum (2019) and Network (2018) respectively, all other variables are sourced from World Bank Development Indicator (WDI Mundial 2018). The variables are all expressed in the logarithmic form with the exception of FDI that is already expressed in percentage of GDP. The UAE data applied in this study cover the sample period of 38, from 1980–2018 (see Table 1 for the summary of the variables with their detailed definition and measurements).

It is expected of FDI to have a positive sign/relationship with an indicator representing the environmental dilapidation in most of the developing countries including the UAE especially at the initial stage of entering the economy. The entering period of FDI into most of the developing economies is assumed to be an open window period with relaxed laws where the sole aim of the country's officials is to attract foreign investors to help in the advancement of the economic performance. Though a positive relationship is expected in the relationship between the environment and FDI, if environmentally regulated policies are initiated to control the excesses of dirty production in the economy, the historical trend of relationship may establish a negative sign thereby given rise to an inverted shape relation. The UAE economic officials are known with some economic laws curtailing the excessive penetration or taking over the economy by the foreign investors thereby making sure that about 50% of each foreign investment in the UAE are owned by UAE citizens. Where stringent laws

Table 1 Summary of variables and their measurements

No	Variable	Short form	Definition/measurements
1	Ecological footprint	EFP	Ecological footprint measured in hectare per capita and expressed in log form (sourced from global footprint network)
2	GDP per capita	GDP (Y)	Gross domestic product (GDP per capita) measured in constant 2010 US$/Log of GDP (sourced from WDI Mundial 2018)
3	GDP per capita squared	GDP (Y^2)	Squared gross domestic product (GDP per capita) measured in constant 2010 US$/log of GDP (sourced from WDI Mundial 2018)
4	Energy use	EU	Energy use (summation of oil and gas, all measured in million tonnes oil equivalent
5	Foreign direct investment	FDI	Foreign direct investment, inflow/as a percentage (%) of GDP (sourced from WDI Mundial 2018)
6	Foreign direct investment squared	FDI^2	Squared foreign direct investment, inflow/as a percentage (%) of GDP (sourced from WDI Mundial 2018)
7	Population	POP	Urban population/log of the population (sourced from WDI Mundial 2018)

Source: Author's compilation

are adequately observed the FDI trajectory in the economy is expected to have the inverted *U*-shaped containing both pollution haven and halo. Therefore, δ_4 and δ_5 in both Eqs. (2) and (3) are expected to have positive (+) and negative (−) signs. The coefficient of energy use, δ_3 is expected to have a positive (+) sign considering the fact that the components of the energy use (natural gas and oil) are purely fossil fuels and are dominating in the energy mix of the UAE. The coefficients of GDP (δ_1) and squared GDP (δ_2) are projected to be positive (+) and negative (−) for the EKC to hold for the UAE (Wang et al. 2012). The expected sign of population (δ_6) parameter is positive following the increasing impacts of population on ecology with limited resources.

The methodology employs in this study stems from different approaches such as detailed summary of statistics (descriptive); stationarity estimates, maximum lag estimation, dynamic, and linear regression with ARDL-bound testing; and VECM causation estimate. A detailed descriptive statistic was undertaken to confirm the stability of the employed data with regard to normality and distribution. The stationarity test was considered among the methods in this analysis because of the complexities surrounding time series data. It is presumed that most time series data have unit root tendencies which can dampen the authenticity of the findings in a time series study. For this, it is essential for ascertaining the pattern of the data employed in times series study through unit root test. This will direct the author's next approach in his research. With regard to the importance of the unit root test, the author adopts various stationarity methods ranging from augmented Dickey and Fuller (1979); Philip-Perron (1990); and Kwiatkowski et al. (1992). Based on the assertions of inevitable unstable data which may sometimes hidden from the conventional unit root test methods, it is recommended for a test of the structural break to expose the shocks capable of influencing the stability of data. Structural break test is employed in this study as a vigorous check to the conventional approaches of unit root testing (Adedoyin et al. 2020a, b; Öztürk et al. 2020; Rafindadi and Ozturk 2017; Adedoyin et al. 2020a, b). Akaike information criterion (AIC) was employed by the author for estimation of optimal lag selection. For the effectiveness of testing and exposing the linear relationship that exist between the explained and explanatory variables which will aid in our finding concerning the two hypotheses (EKC and PHH) highlighted in this present study, autoregressive distributed lag (ARDL) with bound testing was adopted. Diagnostic testing such as serial correlation, heteroscedasticity, and cumulative sum (CUSUM) and CUSUM-sq (CUSUM squared) were also employed to ascertain the stability and reliability of the residuals, data, and the parameters of the selected variables.

Empirical result and discussion

Descriptive statistics

The descriptive statistics among the methods employed in this study are displayed in Tables 2 and 3 below. The output of the statistical analysis shows some level of normality in the data with all the values of the probabilities of Jarque-Bera confirmed insignificant except for the FDI and population. The Kurtosis displayed a light tail and confirmed the normality of the data with all the figures below 3 except for the case of FDI. Moreover, mean, median, maximum, minimum, and standard deviation were all calculated with population, energy, and footprint showing the highest mean and maximum (Table 3).

Stationarity tests

The stationarity test was taken with the traditional methods to ascertain the stationarity of the selected variables. Traditional approaches such as mentioned above were employed by the author to test the unit root and order of integration among the chosen variables. Most of the variables show non-stationarity with a mixed (I(0) and I(1)) order of integration. For the purpose of accounting for structural changes/occurrences capable of creating a long-lasting shock in the economy which the conventional unit root testing might not expose, structural break test equally employed as a robust check to the basic unit root test. The author employs the Zivot and Andrews (1992) method which is the adjustment of the Perron (1990) method. The outputs of both the traditional unit root testing and the structural break test are shown in Tables 4 and 5. Structural changes in the UAE that are likely to cause permanent shocks which are capable of distorting the stability (stationarity) of the data within the time frame of this present study occurred in

Table 2 Descriptive statistics

Variables	EFP	GDP	EU	FDI	POP
Mean	11.48	2.01E+	50.18	1.379	3346.
Median	12.31	1.74E+	46.14	0.408	2233.
Maximum	13.85	3.84E+	109.1	6.767	8047.
Minimum	6.473	9.40E+	9.310	− 1.167	8228.
Std. Dev.	1.931	9.06E+	28.81	1.984	2544.
Skewness	− 0.755	0.536	0.441	1.341	0.858
Kurtosis	2.512	1.922	2.166	3.897	2.151
Jarque-Bera	3.881	3.565	2.276	12.33	5.658
Probability	0.143	0.168	0.321	0.002	0.059
Sum	424.8	7.45E+	1857.	51.05	1.24E+
Sum Sq. Dev.	134.3	2.95E+	2989.	141.7	2.33E+
Observations	37	37	37	37	37

Source: Estimated by author

Table 3 Conventional (ADF, PP, and KPSS) unit root test

Variables	Level		1st Diff		
	Intercept	Intercept & trend	Intercept	Intercept & trend	Order
ADF					
LEFP	− 2.459	− 2.457	− 6.378***	− 4.430***	*I* (1)
LGDP	2.037	− 2.497	− 4.131***	− 4.846***	*I* (1)
LEU	1.234	− 1.385	− 6.364***	− 6.698***	*I* (1)
FDI	− 2.018	− 3.733**	− 3.697***	− 3.633**	Mixed
LPOP	4.451	1.973	− 0.491	− 2.358	*I* (2)
PP					
LEFP	− 2.465	− 3.332*	− 6.346***	− 8.628***	Mixed
LGDP	1.766	− 2.751	− 4.124***	− 4.811***	*I* (1)
LEU	1.364	− 1.270	− 6.379	− 6.698***	*I* (1)
FDI	− 2.167	− 2.766	− 5.848***	− 5.759***	*I* (1)
LPOP	0.733	− 1.617	− 1.821	− 1.821	*I* (2)
KPSS					
LEFP	0.186	0.187**	0.686**	0.132*	
LGDP	0.722**	0.206**	0.494**	0.094	
LEU	0.743**	0.169**	0.363*	0.065	
FDI	0.499**	0.070	0.051	0.051	
LPOP	0.684**	0.176**	0.273	0.092	

Note: Null hypothesis is non-stationary for ADF&PP and stationary for KPSS

The signs depict (*) significant at the 10%; (**) significant at the 5%; (***) significant at the 1%; and (no) not significant

*MacLean and MacKinnon (1996) one-sided *p*-values

the following years: EFP (2009, 1992); GDP (1998, 2009); FDI (2003, 2003); EU (1999, 2007); POP (2001, 2003). The notable shocks that significantly impact the economic stability of most oil-producing countries took place within the 1990s and twentieth centuries. These shocks were observed as great fluctuations in the oil market. The trajectories in the volumes of stocks of crude and oil products determine the short-term price movements. Organization of Petroleum Exporting Countries (OPEC) played a significant role in the demand and supply of crude oil which determines short-term price movements. Among the notable events that caused shocks in the oil market which affected the oil-producing and -exporting countries within the stipulated periods are the Asian 1997 and Russian 1998 crises (Bret-Rouzaut and Favennec 2011).

Table 4 Zivot-Andrew break test

Variables	Ziv-A	Prob	Lg	Break period	CV@ (1%)	CV@ (5%)
LEFP	− 3.841	0.002***	4	2009	− 5.57	− 5.08
LGDP	− 3.354	0.151	4	1998	− 5.57	− 5.08
LEU	− 4.503	0.009***	4	1999	− 5.57	− 5.08
FDI	− 7.979	0.000***	4	2003	− 5.57	− 5.08
LPOP	− 6.283	0.008***	4	2001	− 5.57	− 5.08
DLEFP	− 5.007	0.133	4	1992	− 5.57	− 5.08
DLGDP	− 5.479	0.021**	4	2009	− 5.57	− 5.08
DLEU	− 7.477	0.022**	4	2007	− 5.57	− 5.08
DFDI	− 5.058	0.131	4	2003	− 5.57	− 5.08
DLPOP	− 4.152	0.003***	4	2003	− 5.57	− 5.08

The signs depict (*) significant at the 10%; (**) significant at the 5%; (***) significant at the 1%; and (no) not significant

*MacLean and MacKinnon (1996) one-sided *p*-values

Table 5 Linear estimate with ARDL-bound testing

Variables	Coefficients	SE	*t*-statistics	*P*-value
Short path				
D(LGDP)	8.67E-	3.71E-	2.335	0.034**
D(LGDP)^2	− 4.20E-	1.08E-	− 3.875	0.001***
D(LEU)	0.182	0.056	3.210	0.006***
D(FDI)	− 0.125	0.151	− 0.824	0.423
D(FDI)^2	− 0.055	0.027	− 2.046	0.060*
D(LPOP)	5.56E-	1.14E-	4.872	0.000***
CointEq(−1)*	− 0.535	0.138	− 3.877`1	0.000***
Long path				
LGP	8.67E-	3.71E-	2.335	0.034**
LGP^2	− 4.20E-22	1.08E-	− 3.875	0.001***
LEU	0.182	0.057	3.211	0.006***
FDI	− 0.125	0.152	− 0.824	0.423
FDI^2	− 0.056	0.027	− 2.046	0.060*
LPOP	5.56E-	1.14E-	4.873	0.000***
C	11.64	3.213	3.622	0.003***
R^2	0.979			
Adj. R^2	0.950			
D. Watson	2.478			
Bound test (long path)				
F-stats	10.17***	*K* = 6 @ 1%	*I* (0) = 4.6	*I* (1) = 5.6
Wald test (short path)				
F-stats	33.70***			
P-val	0.000			
Serial correlation test				
F-stats	1.157			
R^2	5.657			
P-val	0.059			
Heteroskedasticity estimate				
F-stats	0.527			
R^2	15.03			
Prob	1.000			

Note: *, **, and *** represent significance at 10%, 5%, and 1% respectively

These crises followed by the Latin America problem slowed the increase in oil demand and eventually caused the cut in oil price from $20/bbl to $10/bbl. This sharp drop in the crude price posed a serious financial problem to most of the oil-producing countries including the UAE and this plunge most of them into serious debt problems. Another significant shock was the terrorist attacks of September 11, 2001, which caused a great collapse in prices. Another incident that introduced a shock in the oil market was in March 2003 following President George W. Bush's pronouncement of inversion of Iraq by a US-led coalition. This brought about a fall in the oil market within the period. Even though the 2003 shock was recorded, it was short-lived by the distortion in the demand and supply of oil which ushered in a rise in both oil production and oil price. This brought about good economic performance in most oil-producing and -exporting countries. The UAE being among the good performing economies during this period maintained a very good and strong economic growth at the rate of 4% per year within the periods of 2003 to 2007. The 2008 global financial recession that lingered to 2009 and a further collapse in oil prices paved way for another great shock which impacted many economies of the world unfavorably. The trends of these shocks were all captured in the structural break analysis of this present study. This confirms the likelihood of unstable (non-stationarity) data of economic indicators within the period of this study (1980–2018).

Linear estimate with ARDL-bound testing

The result of linear regression with the ARDL approach and the diagnostic estimates is displayed in Table 6 below. Among the contents of the table are the *R*-square and adjusted *R*-square, Durbin Watson (DW), serial correlation, and the heteroscedasticity and the bound testing cointegration output. The R^2 and adjusted R^2 remain 0.90 and 0.85 respectively. This means that the explanatory variables (GDP, GDP^2, EU, FDI, FDI^2, POP) explain 90% (0.90) of the dependent variable (EPF). The remaining 10% (0.10) variations in the ecological footprint are accommodated by the residual. The output of Durbin Watson is 2.4, and this falls within the acceptable range for the absence of autocorrelation. The absence of autocorrelation means that the estimation of the model is free from the problem of serial correlation. Among the diagnostic estimates of this study are heteroscedasticity and CUSUM tests. The heteroscedasticity test confirms the absence of non-constant variance of the residual term (error term). This confirmed the presence of homoscedasticity and depicts the normal distribution of error term in a regression model. The output of cumulative sum and cumulative sum square depicts reliability and stability of the model with the blue lines in both tests well fitted in between two red lines. The findings come in Figs. 6 and 7 after the ARDL regression table. The cointegration tests were done with the bound testing approach and the possibility of a long-run relationship was established with the confirmation of cointegration. The cointegration was confirmed with the values of *F*-stats which refutes the null hypothesis of no cointegration at a 1% significant rate. The result is also displayed in the table that contains the linear regression test. The optimal maximum lag selection was performed with the Akaike information criterion (AIC) and the optimal lag was confirmed to be 2. The speed of adjustment is anticipated at − 1.5346 based on the error correction output which is significant at 1%. With the establishment of a negative coefficient and high significance in the error correction model, there is evidence of the long-run relationship and the

Table 6 Short- and long-run VECM Granger causality analysis/block exogeneity Wald tests

Variables										
Short-run path										
	ΔLEFP		ΔLGDP		ΔLEU		ΔFDI		ΔLPOP	
ΔLEFP	√√	√√	11.59***	[0.003]	4.912*	[0.085]	4.906*	[0.086]	33.40***	[0.000]
ΔLGDP	1.217	[0.543]	√√	√√	0.487	[0.783]	3.090	[0.213]	16.05***	[0.000]
ΔLEU	1.521	[0.467]	0.643	[0.724]	√√	√√	2.491	[0.287]	8.549**	[0.013]
ΔFDI	1.186	[0.552]	2.916	[0.232]	3.219	[0.199]	√√	√√	30.73***	[0.000]
ΔLPOP	1.640	[0.440]	6.926**	[0.031]	6.330**	[0.042]	3.203	[0.201]	√√	√√
Long-run path										
	LEFP		LGDP		LEU		FDI		LPOP	
LEFP	√√	√√	3.262*	[0.070]	3.415*	[0.064]	0.217	0.641	13.94***	[0.000]
LGDP	1.224	[0.268]	√√	√√	0.735	[0.390]	0.386	0.534	10.25***	[0.001]
LEU	1.142	[0.285]	7.599***	[0.005]	√√	√√	0.296	0.585	11.03***	[0.000]
FDI	0.793	[0.373]	5.531**	[0.018]	3.390*	[0.065]	√√	√√	7.747***	[0.005]
LPOP	1.241	[0.265]	3.114*	[0.077]	5.156**	[0.023]	0.925	0.335	√√	√√

Note: *, **, and *** represent 10%, 5%, and 1% significance resp. Figures in [ ] are prob while the figures before the brackets are the chi-squares (χ^2) = chi-squares (χ^2) [*p*-values]

possibility of forming equilibrium in the long-run time. Findings from the linear (ARDL) regression are as follows:

A positive, but on a low scale (elasticity), and significant relationship between economic growth (GDP) and environmental performance (ecological footprint) is recorded both in the short run and long run for all the models, while in the case of squared GDP, a negative, but also on a low scale, with the significant relationship is found between the income (GDP) and environmental performance (footprint). The signs recorded in the findings are in line with the author's expectations (positive and negative) which confirms the existence of the EKC hypothesis with an inverted *U*-shaped relationship between economic growth and environmental quality for the case of the UAE. This shows that an increase in economic growth (GDP) causes a decrease in the quality (poor condition) of the environment (i.e., increase ecological footprint) both in the short run and long run, while for the case of squared GDP, economic growth causes an increase in the quality (good condition) of the environment (i.e., decrease ecological footprint) for the short run and long run. This is expressed quantitatively as a percentage point change in economic growth increases ecological footprint both in the short run and long run in a low scale (8.67E-11). Likewise, for the squared GDP, a percentage point change in economic growth (GDP) causes a decrease in ecological footprint both in short run and long run in a low scale (− 4.20E-22). This is a good and successful trend for the sustainability story of the UAE in economic performance and environmental performance.

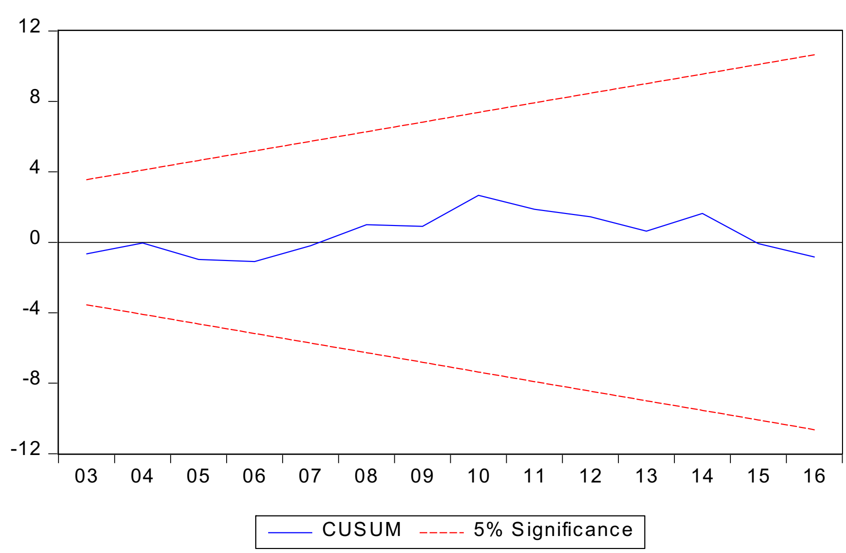


Fig. 6 Plot of the cumulative sum of recursive residuals. The blue line is the solid line while the red lines that bounded the blue line are the critical bounds at 0.05

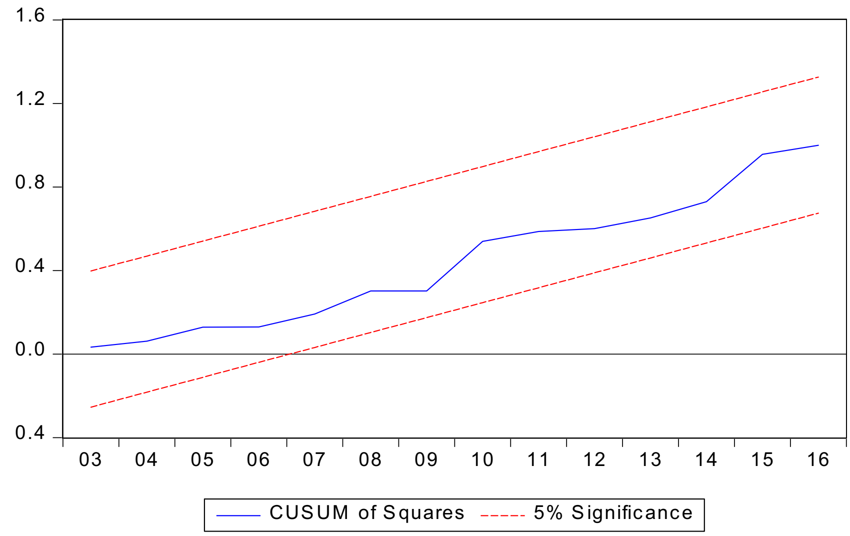


Fig. 7 Plot of cumulative sum squared of recursive residuals. The blue line is the solid line while the red lines that bounded the blue line are the critical bounds at 0.05

These findings conform with the findings of Charfeddine and Khediri (2016) for the UAE; Gill et al. (2018) for the world; Ozatac et al. (2017) for Turkey; Basarir and Arman (2014) for the UAE; Shahbaz et al. (2013a, 2013b) for the UAE; Shahbaz et al. (2014) for the UAE; Ozcan (2013) for the Middle East; Sbia et al. (2017) for the UAE; and Sarkodie and Ozturk (2020) for Kenya. A positive and significant relationship is revealed among the energy and environment quality in the short run and long run respectively. This suggests an increase in energy use causes a decrease in the quality (poor condition) of the environment (i.e., increase ecological footprint) both in the short run and long run. This means that a percentage point change in energy use causes a 0.18% increase in the deplorable state of the environmental performance (ecological footprint). This supports the author's expected sign from the analyses. This is anticipated in the case of the UAE following the energy mix as represented in Fig. 4. Fossil fuels (natural gas and oil) are dominating the energy utilization in the UAE, and it is a known fact that fossil fuels give rise to higher emissions. This finding is consistent with the findings of Charfeddine and Khediri (2016) for the UAE; Ozatac et al. (2017) for Turkey; Basarir and Arman (2014) for the UAE; Shahbaz et al. (2013a, 2013b) for the UAE; Shahbaz et al. (2014) for the UAE; Udemba et al. (2019) and Udemba et al. (2019) for China; and Udemba 2020a, b, c).

A negative and but insignificant relationship exists between FDI and the environmental performance (ecological footprint) both in the short run and long run in the first stage. Quantitatively, a percentage point change in FDI causes a − 0.125% decrease in ecological footprint (i.e., improving environment quality). The same trend is seen in the squared term of FDI except on the significance basis. Thus, a negative and significant relationship is established between FDI and environmental performance (ecological footprint). A percentage point change in FDI causes a − 0.0556% decrease in ecological footprint (i.e., improving environment quality). This does not follow an inverted *U*-shaped relationship between the environmental performance and FDI as anticipated by the author; rather, a flat pattern of relationship is uncovered between the environmental performance and FDI. The only variation was on the significance of the impact which is obvious in the squared FDI. The impact of squared FDI on environmental performance is significant at 10% and depicts a success story in the historical impact of FDI on environmental quality. This is not a surprise even though the author hypothesized an inverted *U*-shaped relationship. Studies on the impacts of FDI on the UAE economy and energy efficiency proved that FDI is energy efficient in the UAE economic performance (Sbia et al. 2014). In the research carried by Sbia and friends, they found FDI negatively linked with energy consumption at a 1% significant rate. The easy access to both capital and income which remains the center of attraction for FDI into UAE aids in green production void of excess pollution because of technological innovation in the country. Aside from innovations and technological transformation, the UAE is known for different green building initiatives targeting the balancing of energy utilization and environmental performance. Among the initiatives is the implementation of a new energy rating system on all domestic machines by the Emirates Standardization and Metrology Authority (ESMA). Another finding from the linear perspective is the positive (elasticity) but low in scale and significant connection among the urban populace and the environmental performance (ecological footprint) both in the short run and long run. Hence, a 1% point change in the urban population caused 5.56E-05% increase in the ecological footprint both in the short run and long run. This result reveals the increase in the poor environmental (poor quality) performance due to population increase in the emirate. This can be justified with the increase in the emirate's population especially as it pertains to urbanization within the cities of Dubai and Abu Dhabi. This is in conformity with the works of Ulucak and Khan (2020) and Nathaniel et al. (2020). The rise in population will definitely result in an increasing rate of demand and consumption of natural resources such as energy and food. Considering the meaning of ecological footprint as human pressure or activities calculated in terms of occupied land and water needed for the production of goods for consumption and the assimilation of the waste in the area, it means the increasing pressure from the increasing population is degrading the quality of the environment. This is shown in Fig. 1 which depicts the household as the sector with the highest footprint at 57% followed by business and industry at 30% before government at 12%.

Diagnostic tests

Residual stability (CUSUM and CUSUM squared)

Cumulative sum (CUSUM) and CUSUM-sqr (CUSUM squared) were also employed to ascertain the stability and reliability of the residuals, data, and the parameters of the selected variables. The output of cumulative sum and cumulative sum square depicts reliability and stability of the model with the blue lines in both tests well fitted in between the two red lines. This is shown in Figs. 6 and 7.

Granger causality analysis (VECM)

For a robust check to the linear analysis in this current study, the Granger causality estimate was employed by the author. In some cases, there are misinterpretations of the linear output. This usually occurs based on the kind (sign) of the relationship that exist between the selected variables. The linear analysis only ends in establishing the relationship that exist between the variables (dependent and the explanatory variables) without insight on the path of the association among the selected variables. Granger causality gives an in-depth explanation as regards the movement or direction of the impact (i.e., which among the variables is impacting the other, one-way or two-way direction). The Granger causality in this present work is anchored on VECM Granger causality after establishing the existence of long-run association through bound testing. The empirical output of both the short run and long run (block exogenous/VECM) Granger causality are reported in Table 7.

In the long run, a two-way direction or feedback (bidirectional) is exposed between economic performance (GDP) and urban population and between energy use and urban populace. Also, a one-way transmission (unidirectional) from the ecological footprint and FDI to population; from the ecological footprint, energy use, and FDI to economic growth; and from the ecological footprint and FDI to energy use. Just like in long run, the author found a two-way transmission (bidirectional) among economic performance (GDP) and urban population and between energy use and urban population in the short run. A one-way transmission (unidirectional) was found passing from ecological footprint and FDI to population and from ecological footprint to FDI and energy use.

Conclusion and policy implications

As the title of this study suggests, the author researched the possibility of achieving carbon neutral in the economic and environmental performance of the UAE. A careful selection of indicators was done based on their relevance to the objective of this study. The ecological footprint was selected as the indicator to measure the environmental performance (quality of the environment) based on the complex nature of research and the comprehensive nature of the ecological footprint which encompass six (6) components of environments. Aside from ecological footprint, GDP per capita, FDI, and population were considered relevant to the purpose of this research with squared GDP per capita and FDI. Specifically, the author anchored this study on EKC and PHH hypotheses to uncover the pattern of relationship that exist between the economic performance (economic growth), FDI, and environmental performance which will give insight into the possibility of carbon neutrality. In order to achieve this purpose, the present study employs squared of both GDP per capita and FDI which will assist the author to uncover the pattern of the relationship (*U*-shaped, inverted *U*-shaped, N-shaped, or flat pattern shape). The author employs empirical analyses such as structural break analysis, linear estimation with ARDL-bound testing, and causal analysis with VECM with detailed explanations of the findings of each analysis.

Apart from deviating from the expectation of the author as regards the shape of the relationship between FDI and environmental performance, all other findings fall in line with the expectation of the author. The deviation from the expected inverted *U*-shaped to a flat pattern of relationship strengthens the anticipation of carbon neutral in the UAE. The flat pattern of relationship is formed under negative relationship which portrays a success story for the possibility of carbon neutral and sustainable development in the UAE. Among the findings from linear estimates are inverted *U*-shaped relationship between economic growth (GDP per capita) and ecological footprint which confirms EKC for the UAE, positive relationship between energy use and ecological footprint, negative relationship between FDI and ecological footprint in all stages which established a flat pattern of relationship, and a positive relationship between the population and ecological footprint. Findings from causal analyses exposed a two-way direction or feedback (bidirectional) is found between economic performance (GDP) and urban population and between energy use and urban populace both in the short and run. Also, a one-way transmission (unidirectional) from the ecological footprint and FDI to the population both in the short run and long run; from the ecological footprint, energy use, and FDI to economic growth; from the ecological footprint and FDI to energy use in the long run, and from ecological footprint to FDI and energy use in the short run. These findings really confirm the sensitive position of the population in determining the ecological footprint of the UAE through the active impact of the population on both economic growth and energy utilization. Even though there is no direct transmission established between ecological footprint and the three factors (GDP, EU, and POP) in the long run, a nexus is confirmed among economic growth, energy use, and population which is expected to have an indirect impact on the ecological footprint of the UAE. Worth noting is the unidirectional causal impact from ecological footprint to economic performance (GDP per capita), FDI, and energy use. This is backed with the findings from the linear estimate (positive relationship between ecological footprint and population and between ecological footprint and economic growth at the linear stage) and the sectorial contribution to the UAE ecological footprint (Fig. 1). These findings have great implications for the neighboring countries especially the six (6) Golf countries who have similar environmental exposure due to natural resources and the ease to access capital for investment. With insight from this study and policy suggestions, the Gulf countries will equally benefit from this research.

However, having gotten a realistic view of the current state of the UAE environment and the significant urban population impact, the policy focus should be towards the improvement on the urban population. This should be done through sensitization of the public and awareness on the importance of curbing carbon emission. With the current Masdar initiative of the world's first carbon-free city, new green building regulations should be encouraged to reduce the UAE footprint. This initiative is targeting the diversification of energy sources to more renewable sources. Also, the policy should be implemented to regulate the energy-consuming products mainly used in the housing sector to be more energy efficient. The transportation sector should be improved by making provision for increasing availability of public mass transit systems such as metro and light rail. This will have a spillover effect on the rate of car usage by the masses who will prefer the mass transport system. This will equally impact the rate of petrol and gas consumption among the households. The Carbon Capture and Storage (CCS) initiative by the UAE should be developed and implemented within a realizable time frame with seriousness. Moreover, the FDI pattern suggests the pollution halo hypothesis which is a pointer towards its (FDI) crucial contribution to environmental performance. This is possible through the introduction of friendly technology from developed countries by FDI. Hence, FDI should be encouraged through relaxing of some laws that are preventive in nature towards FDI so as to maintain this positive trend towards sustainable development.

Conclusively, as noted in the introductory part of this study, in the midst of energy-intensive growth and development of the UAE economy, there is still some hope of revamping the climate change in the country through a deliberate policy framework. The good thing about the energy production and consumption trend in the UAE economy is the adoption of vision 2021 which agenda is to diversify the investment of the country into other non-energy sectors. Diversifying the investment into non-energy such as infrastructure and technology and services will help in sustainable development.

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Author contributions The paper is written by just one author, and the contributions are purely and majorly by Edmund Ntom Udemba, Faculty of Economics Administrative and Social sciences Istanbul Gelisim University, Istanbul, Turkey. Email: eudemba@gelisim.edu.tr; eddy.ntom@gmail.com; Tel: +905357808713; WhatsApp: +2347039678122.

Declarations

Ethics approval and consent to participate I, the author is giving my ethical approval and consent for participation in this paper to be published in ESPR if found publishable

Consent for publication I, the author is giving my consent for this paper to be published in ESPR if found publishable

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