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Research paper

Determinants of carbon emissions in Argentina: The roles of renewable energy consumption and globalization

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ABSTRACT

This study aimed to evaluate the dynamic effects of globalization, renewable energy consumption, non-renewable energy consumption, and economic growth on carbon-dioxide emission levels in Argentina over the 1970–2018 period. The econometric methodology considered in this study involved applications of methods that are robust to handling structural break problems in the data. Among the major findings, the Maki cointegration, with multiple structural breaks, analysis revealed long-run associations between carbon-dioxide emissions, renewable and non-renewable energy consumption, globalization, and economic growth. The elasticity estimates from the Autoregressive Distributed Lag model analysis showed evidence of renewable energy consumption and globalization reducing the emissions while non-renewable energy consumption was found to boost the emissions, both in the short- and long-run. Besides, globalization and renewable energy consumption were found to jointly reduce the emissions while globalization and non-renewable energy consumption were found to jointly boost the emissions in the long-run only. Moreover, the environmental Kuznets curve hypothesis was also verified in this study. Based on these key findings, several critically important policies are recommended.

1. Introduction

Environmental degradation has taken central attention in most climate change-oriented discussions among global leaders (Murshed et al., 2021a). As a result, a plethora of studies has tried to scrutinize the macroeconomic factors responsible for the aggravation of the global environment (Qin et al., 2021; Pata and Caglar, 2021; Khan et al., 2021). These studies predominantly focused on discovering how economic growth can be accelerated without damaging the environment. Besides, tackling environmental degradation and the associated adversities has also received global recognition through the environmental protection commitments of the world economies under different climate treaties and conventions such as; the Kyoto protocol, the Intergovernmental Panel on Climate Change (IPCC), and the Paris agreement (Murshed, 2021a; Murshed et al., 2021b). These agreements have stipulated the industrialized economies and emerging markets, in particular, to adopt relevant policies that would facilitate the reduction of emissions of Greenhouse Gases (GHGs) into the atmosphere. However, despite the ratification of these agreements, the global GHG emission levels continue to surge. It has been estimated that the global Carbon dioxide emission (CO_2) figure reached its all-time highest level of around 33.1 megatons of oil equivalent in 2018, which tends to highlight the failure of the world economies to comply with their atmospheric pollution mitigation commitments.

This phenomenon is particularly alarming in the context of emerging market economies. According to a report published by the IPCC, emerging market economies are alleged to prioritize economic growth over environmental well-being whereby these nations expanded the size of their respective economies while accounting for almost 76.6% of the global GHG emissions, particularly CO_2 (Destek and Aslan, 2017). Among the different emerging

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market economies across the world, Argentina has been acknowledged as one such nation which has conventionally implemented policies to boost economic growth while overlooking the environmental deterioration which took place in tandem (Koengkan et al., 2020). Argentina is the largest emerging economy in Latin America which has traditionally globalized its economy in quest of expediting its economic growth rate. Consequently, although the nation had prospered economically, it has resulted in the aggravation of its CO_2 emission figures. For instance, between 2000 and 2018, Argentina's annual per capita GDP and CO_2 emissions have simultaneously surged by around 22% and 8%, respectively (World Bank, 2020). The rising trends concerning both these key macroeconomic aggregates can be credited to Argentina's globalization policies which have monotonically facilitated the nation's decisions to globalize its economy to expedite economic growth. Accordingly, the nation's trade openness index, measured in terms of the percentage share of exports and imports in the GDP, rose by almost 8 percentage points over the 2000–2020 period (World Bank, 2020). On the other hand, the nation's annual percentage shares of Foreign Direct Investment (FDI) inflows in the GDP have almost doubled between 2001 and 2019 (World Bank, 2020). Therefore, these rising trends in the shares of international trade flows and FDI inflows along with the persistently surging trends in Argentina's CO_2 emission levels suggest that the nation's trade and financial globalization policies have not been environmentally friendly.

The possible negative environmental consequences associated with globalization in the context of Argentina could be explained from the perspective that globalization, over the years, is likely to have boosted the overall energy demand of the nation which has mostly been met with fossil fuels. Almost 72% of Argentina's total electricity, as illustrated in Fig. 1, is generated from non-renewable fossil fuels. As far as the shares of different fuels in the total electricity output are concerned, Fig. 1 shows that natural gas and coal accounts for the largest and smallest shares, respectively. More importantly, Argentina's traditional fossil fuel dependency is further highlighted from the fact that the nation generates merely 28% of its electricity output using renewable sources (mostly hydropower); moreover, between 1990 and 2015, the renewable electricity output shares have on average declined by 7 percentage points. Hence, it can be said that, during this period, Argentina rather than moving towards a clean energy transition has boosted its reliance on fossil fuels for meeting its local energy demand. A major barrier faced by the nation in undergoing the clean energy transition was the lack of investments concerning the development of renewable energy technologies. Consequently, the nation was obliged to import hefty amounts of oil to manage its domestic energy demand (World Bank, 2020) which further reduced the nation's renewable electricity output shares. However, recently, following the enactment of Law 27.191, investments in renewable energy have increased as the Argentine government declared the national objective of boosting the renewable electricity shares to 20% and 25% by 2025 and 2031, respectively. Hence, underscoring the importance of achieving these targets, it is necessary to examine whether or not such initiatives to promote renewable energy use, and simultaneously inhibiting non-renewable energy consumption as well, would be effective in improving environmental quality in Argentina.

Therefore, considering the potential environmental consequences of globalization and energy use, this study investigates the dynamic effects of globalization and energy consumption on CO_2 emissions in Argentina and also controls for economic growth within the analysis. The contributions of this current study to the literature are four-folds. First, although many previous studies have scrutinized the macroeconomic determinants of CO_2 emissions using panel data sets on Latin American countries (Sheinbaum et al., 2011; Koengkan and Fuinhas, 2020a; Adebayo et al., 2021), a country-specific study in the context of Argentina is yet to be conducted. Though cross-country studies are important, conducting country-specific studies is pertinent to identify specific policies considering the country-specific properties of a certain country. Second, as opposed to the traditional approach of evaluating the environmental effect of aggregate energy consumption, this study isolates the impacts of consumption of different energy resources (renewable and non-renewable) on CO_2 emissions in the context of Argentina. Disaggregating the energy consumption figure is important because it has been acknowledged in the literature that renewable and non-renewable energy uses exert heterogeneous impacts on CO_2 emissions (Chen et al., 2019; Murshed, 2020).

Third, the preceding studies have predominantly explored the individual impacts of globalization and renewable and non-renewable energy use on CO_2 emissions (Shahbaz et al., 2017; Khan et al., 2019); but not much is known regarding the possible joint impacts of these variables. Hence, this study interacts globalization with renewable and non-renewable energy consumption to explore the interactive impacts of these variables on Argentina's CO_2 emission figures to unearth some additional policy implications. Lastly, to account for the structural breaks in the data, the methodology used in this study is robust to handling this issue. It is important to control for the structural break within the estimation process since overlooking this critically important issue could lead to the estimation of biased outcomes. The majority of the relevant studies in the literature have not controlled for the structural break issue to model the determinants of CO_2 emissions (Ali et al., 2020). Hence, this study bridges this methodological gap in the literature by employing the Zivot and Andrews (1992) unit root test, Maki (2012) cointegration test, and the gradual shift causality test to ascertain the integrating and cointegrating properties and causal relationships among the variables, respectively. Besides, structural break dummies are also included in the model to control for the structural break concerns within the regression analysis.

The remainder of the paper is organized as follows: the literature review is discussed in Section 2 while Section 3 explains the data and the econometric approach of the study; the study's comprehensive assessments are discussed in Section 4; finally, Section 5 concludes with relevant policy implications.

2. Literature review

This section has two broad segments in which the former provides a brief overview of the theoretical framework of the study while the latter summarizes the corresponding empirical literature.

2.1. Theoretical framework

The exploration of the energy–economy–environment enigma has ramified over the years; thus, splitting the literature into three strands. The first strand of literature closely looked at the links between GHG emissions and economic growth through the lens of the Environmental Kuznets Curve (EKC) hypothesis introduced in the study by Grossman and Krueger (1991). The core assumption of this theory is that an economy initially grows at the expense of environmental adversity; however, this trade-off gradually decreases in the future as the economic growth in the latter phases facilitates environmental development (Yilanci and Pata, 2020). The initial negative impacts of economic growth on the environment can be reason from the perspective of scale effect and composition effects which assert that as an economy starts to grow, its production process changes to employ more

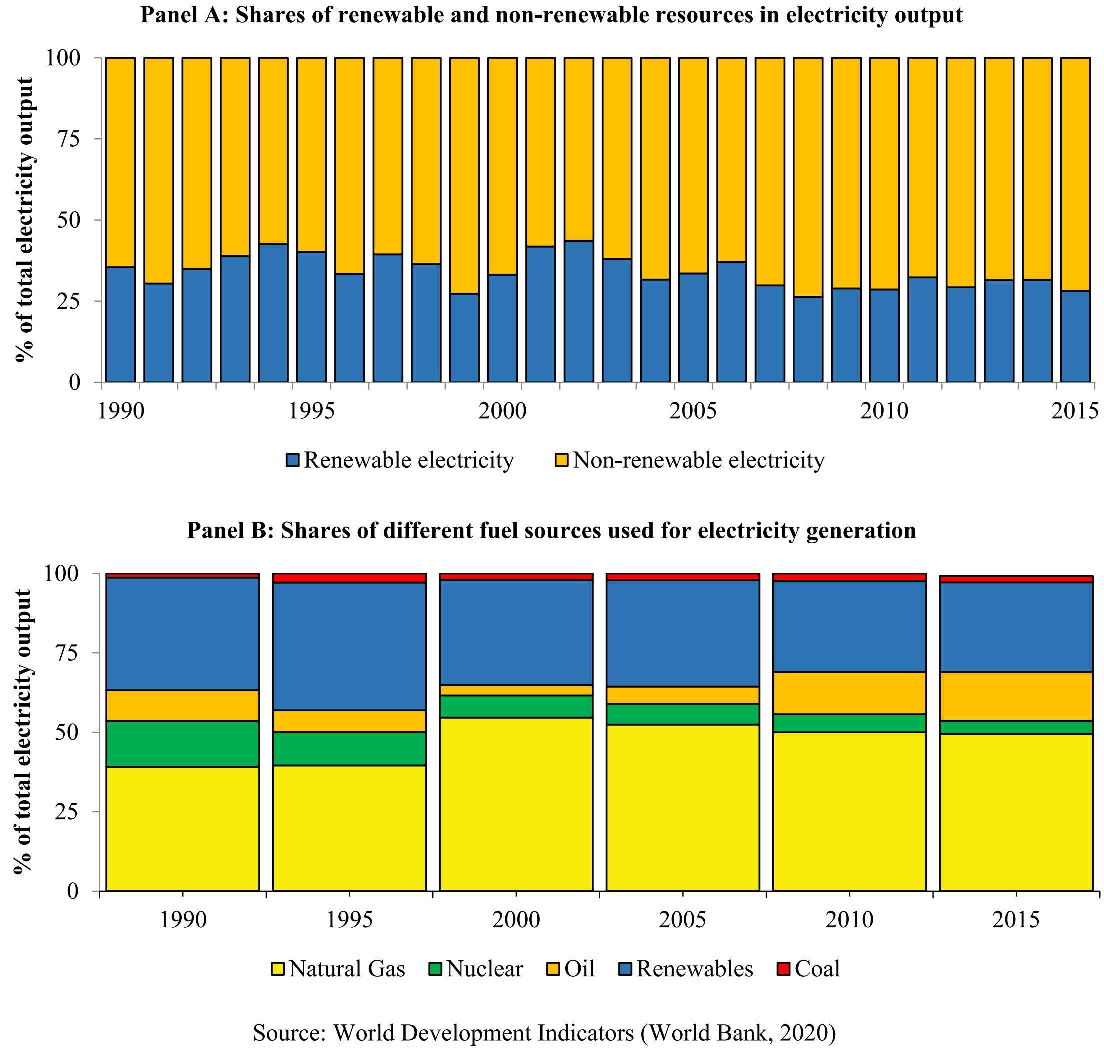

Fig. 1. Trends in renewable and non-renewable electricity outputs in Argentina.
Source: World Development Indicators (World Bank, 2020).

pollution-intensive inputs; consequently, economic expansion results in the deterioration of the environmental quality (Bibi and Jamil, 2021). On the other hand, the complementarity between economic and environmental well-being can be hypothesized to take place through the technique effect which asserts that in the latter stages of development technological innovation facilitates economic growth without adversely impacting the environment (Tenaw and Beyene, 2021). However, the EKC hypothesis has often been criticized due to having a narrow focus in terms of considering economic growth as the only determinant of environmental quality. Hence, the recent studies on the EKC hypothesis have controlled for other key macroeconomic aggregates which affect both economic growth and environmental quality.

The second strand of the literature on the energy–economy–environment nexus further investigated how energy consumption affects environmental quality and, more importantly, how it affects the economic growth–environmental quality nexus. Energy is considered a critically important factor of production whereby a rise in the energy consumption level can be thought to boost economic output (Mehrara, 2007). At the same time, higher energy consumption can also influence the environmental quality since the combustion of energy resources, especially fossil fuels, result in the emission of GHG; thus energy consumption can be alleged to cause harm to the environment (Joshua Sunday Riti, 2016; Allard et al., 2018). On the other hand, the use of renewable energy as an alternative to fossil fuels is said to mitigate energy consumption-related environmental problems (Sinha and Shahbaz, 2018; Adebayo et al., 2020). Furthermore, the integration of renewable energy into the energy mix is believed to gradually lessen the fossil fuel dependency to achieve environmentally friendly economic growth.

In the third strand of the literature on the energy–economy–environment nexus, other macroeconomic variables along with energy consumption are controlled for with the EKC analysis (Haseeb et al., 2018; Zafar et al., 2019a). Among these, globalization is recognized as a major factor that influences economic growth, energy consumption, and economic growth. Globalization is viewed as a mechanism of achieving economic growth as it helps a local economy participate in international trade, attract Foreign Direct Investments (FDI), and connect with the world economies through various other channels. However, the environmental impact associated with globalization can be ambiguous. For instance, globalization through international trade can promote the development of pollution-intensive industries within the developing nations, in particular; whereby globalization can be viewed as a source of environmental degradation (Sánchez-Chóliz and Duarte, 2004). Conversely, globalization-induced international trade can also be a means of specializing in the production of cleaner industries whereby globalization can be expected to work in favor of environmental prosperity as well (Shahbaz et al., 2013a). Similarly, globalization through FDI flows can also exert ambiguous environmental impacts based on whether the FDI are clean or dirty (Doytch, 2020).

2.2. Empirical evidence

2.2.1. Carbon emissions and economic growth

The impacts of economic growth on environmental pollution have popularly been evaluated in light of the EKC hypothesis. Over the last five decades, researchers have tested the validity of the EKC hypothesis and arrived at different conclusions. Among the country-specific studies, Koc and Bulus (2020) employed the Autoregressive Distributed Lag (ARDL) model approach and found the EKC hypothesis to be invalid. The authors asserted that although economic growth initially boosts CO_2 emissions and later on reduces CO_2 emissions, further growth of the South Korean economy once again triggers CO_2 emissions. Hence, the authors concluded that the EKC for South Korea is N-shaped and not inverted U-shaped as postulated in the EKC theory. Likewise, Pata and Caglar (2021) recently employed the augmented ARDL approach and found the EKC hypothesis for CO_2 emissions to be invalid in the context of Turkey. Conversely, in another relevant study on Pakistan, Ali et al. (2020) asserted that the economic growth–CO_2 emission nexus depicts the inverted U-shape; thus, the authenticity of the EKC hypothesis was verified. Similarly, Rana and Sharma (2019) also statistically verified the existence of the EKC hypothesis in the context of India.

Among the cross-country studies on the EKC hypothesis for CO_2 emissions, Dong et al. (2018) used data for 14 Asia-Pacific nations and found the EKC hypothesis to be valid. Besides, the authors concluded that the use of relatively cleaner energy resources plays a major role in validating the EKC hypothesis for these nations. In contrast, in the context of selected newly industrialized economies, Rahman et al. (2021) recently concluded that the EKC hypothesis does not hold for these countries. In other cross-country studies on Latin American nations, Sapkota and Bastola (2017) used annual data from 1980 to 2010 for 14 Latin American nations including Argentina, and found that the EKC hypothesis for CO_2 emissions holds for these nations. In another study on 21 Latin American and Caribbean nations including Argentina, Bibi and Jamil (2021) verified the authenticity of the EKC hypothesis using CO_2 emissions as an indicator of environmental quality.

2.2.2. Carbon emissions and energy consumption

In the past, the majority of the studies have focused on the impacts of aggregate energy consumption on CO_2 emissions. Among these, Shahbaz et al. (2013b) used the ARDL method and opined that a rise in the level of energy consumption is associated with a simultaneous rise in the CO_2 emissions figures of Malaysia. The authors also asserted that since Malaysia meets a large proportion of its energy demand using fossil fuels; consequently the positive correlation between energy consumption and CO_2 emissions is not unrealistic. Likewise, in the context of another fossil fuel-dependent nation like Turkey, Halicioglu (2009) also used the ARDL model and found evidence of energy consumption being responsible for greater emission of CO_2 into the atmosphere. Using a similar methodical approach, Khan et al. (2020) found similar adverse environmental impacts of energy consumption, mostly fossil fuels, on Pakistan's CO_2 emissions. Besides, the authors also remarked that energy consumption boosts the nation's CO_2 emission figures both in the short and long run. On the other hand, Acheampong (2018) used panel data of 116 countries between 1990 and 2014 and found that energy consumption leads to lower CO_2 emissions in selected countries belonging to the Sub-Saharan Africa and Latin America and Caribbean regions which included Argentina as well. On the other hand, the author stated that higher energy consumption boosts CO_2 emissions across countries from the Middle East and North Africa (MENA).

Although the above-mentioned studies have primarily assessed the environmental impacts associated with total energy use, several existing studies have also scrutinized the impacts of renewable and non-renewable energy use of CO_2 emissions (Boontome et al., 2017; Murshed, 2021b; Murshed et al., 2021c). In a study on China over the 1980–2014 period, Chen et al. (2019) employed the ARDL model and concluded that cleaner energy consumption is favorable for improving environmental quality since renewable and non-renewable energy consumptions were found to inhibit and trigger CO_2 emission levels, respectively. Similarly, Pata (2021) also found evidence of renewable energy consumption reducing CO_2 emissions in the United States while non-renewable energy consumption boosting the emission figures in the long run. Similarly, among the relevant cross-country studies, Zafar et al. (2019b) used data of 18 emerging economies between 1990 and 2015 and found renewable energy use to be effective in curbing CO_2 emissions while non-renewable energy was found to stimulate greater volumes of CO_2 into the atmosphere.

Likewise, the favorable environmental outcomes of renewable energy use were also put forward in the study by Bilgili et al. (2016) for 17 Organization for Economic Cooperation and Development (OECD) nations. The authors found statistical evidence of a rise in the level of renewable energy use being responsible for lower CO_2 emissions in the long run. In another similar study on 34 emerging economies from the Sub-Saharan African region, Hanif (2018) concluded that replacing fossil fuels with renewable substitutes can be effective in curbing the CO_2 emission figures of these nations. Recently, Koengkan et al. (2021) also found evidence of renewable energy use leading to lower CO_2 emissions in the context of 19 Latin American nations including Argentina. Besides, the authors also opined that non-renewable energy use across Latin America is responsible for the CO_2 emission woes of the countries belonging to this region. On the other hand, Nathaniel and Iheonu (2019) concluded that although non-renewable energy use is linked to higher CO_2 emission levels in selected African nations, renewable energy use cannot explain the variations in the CO_2 emission figures of these nations.

2.2.3. Carbon emissions and globalization

Several existing studies have scrutinized the environmental impacts associated with globalization using both country-specific and cross-country analysis methods. The finding in this regard has been ambiguous as the existing studies revealed both favorable and adverse environmental impacts associated with globalization. Among the single country studies, Shahbaz et al. (2017) asserted that globalization is a credible means for China to lower its CO_2 emission figures. The authors found evidence of globalization negatively impacting the CO_2 emission levels both in the short- and long run. Besides, the authors also CO_2 emissions causally influence globalization without the feedback causation. Similarly, Salahuddin et al. (2019) explored the globalization–CO_2 emissions nexus in the context of South Africa between 1980 and 2017. Employing the ARDL technique, the authors claimed that globalization does not influence the CO_2 emission levels of South Africa in the short-run but in the long-run globalization triggers CO_2 emissions. Besides, the authors also stated that there is no causal association between these variables in the case of South Africa. Mehmood (2021) explored the effects of economic and political globalization on Singapore's CO_2 emission figures between 1970 and 2014. The results from the ARDL analysis showed that a rise in the value of the globalization indices would enforce a reduction in the nation's CO_2 emissions in the long run.

Table 2
Variables of the study and their descriptions.

Variable	Description	Units	Sources
CO_2	Environmental sustainability	Metric tons per capita	WDI
GDP	Economic growth	GDP per capita (constant 2010 US$)	WDI
NREN	Non-renewable energy consumption	Non-renewable energy consumption per capita (kWh)	WDI
REN	Renewable energy consumption	Renewable energy consumption per capita (kWh) per capita	WDI
GLO	Economic globalization	Index	KOF index.

* WDI—World development indicators World Bank (2020), ** KOF Index—its revised KOF globalization index (Gygli et al., 2019).

In the existing cross-country literature on the globalization-CO_2 emissions nexus, Yang et al. (2021) used annual data from 1971 to 2016 for selected OECD countries and found economic globalization negatively impacting the CO_2 emissions figures of these nations. Hence, the authors claimed that globalization can be the panacea to the environmental pollution issues of the OECD countries. Recently, Nathaniel et al. (2021) showed that globalization in selected Latin American and Caribbean nations, including Argentina, triggers the emissions of CO_2. Similar conclusions in the context of 18 Latin American and Caribbean nations were also reported by Koengkan et al. (2021). On the other hand, Haseeb et al. (2018) examined this nexus in the context of the BRICS nations and found that globalization is not effective in influencing the CO_2 emission figures of these emerging nations. Liu et al. (2020), for the Group of Seven (G7) countries between 1970 and 2015, documented evidence of globalization initially causing environmental degradation by boosting the CO_2 emission levels. However, later on, further globalization leads to environmental welfare through the reduction in the CO_2 emission figures of these developed countries. Table 1 (in the Appendix) provides a summary of the relevant empirical literature on the impacts of economic growth, renewable energy consumption, and globalization on CO_2 emission.

2.3. The literature gaps

It is clear from the review of the relevant literature that although the impacts of economic growth, renewable energy use, and globalization on CO_2 emissions in the context of Argentina have been evaluated within the cross-country studies, not much emphasis has been given to assess these relationships specifically in the context of Argentina. Besides, the majority of the studies have assessed the effects of total energy consumption on CO_2 emissions whereas the literature on disaggregated (renewable and non-renewable) energy–CO_2 emissions nexus is relatively limited. More importantly, none of the preceding studies have attempted to model the impacts of renewable and non-renewable energy use on Argentina's CO_2 emission figures. Besides, almost all the studies have explored the isolated impacts of energy consumption and globalization on CO_2 emissions whereas little is known regarding the possible joint impacts of these variables. Lastly, it is also evident from the literature that the existing studies have largely overlooked the structural break issues in the data. Consequently, the findings documented in the literature can be biased to some extent. Therefore, this current study attempts to bridge these aforementioned gaps in the literature by scrutinizing the impacts of economic growth, renewable energy use, and globalization on Argentina's CO_2 emission figures between 1970 and 2018. The following questions are addressed in this study:

1. Does renewable and non-renewable energy consumption exert heterogeneous impacts on Argentina's CO_2 emission figures?
2. Can globalization help to inhibit CO_2 emissions in Argentina?
3. Is there any joint impact of energy use and globalization on CO_2 emissions in Argentina?
4. Does the EKC hypothesis for CO_2 emissions hold for Argentina?

3. Data, model specification, and empirical modeling

3.1. Data

The study utilizes secondary sources to compile annual time series data from 1970 to 2018 in the context of Argentina. The choice of this time period was purely based on the availability of the most recent information. In this study, the dependent variable is the CO_2 emission per capita figure of Argentina which is used as a proxy for environmental quality. The independent (explanatory) variables include non-renewable energy use, renewable energy use, and economic growth. The non-renewable and renewable energy consumption figures are measured in terms of kilowatt-hours (kWh) per capita. Besides, following Haseeb et al. (2018), Kalayci and Hayaloglu (2019) and Koengkan et al. (2020), economic globalization is the type of globalization used in this study that is measured as an index based on FDI, trade, and portfolio investments. The description, unit of measurement and sources of the selected variables are further shown in Table 2. Furthermore, the variables economic growth, CO_2 emissions, non-renewable energy consumption, and renewable energy consumption are transformed into their natural logs to predict the elasticities of CO_2 emissions.

3.2. Model specification

Based on the discussion above, we introduced economic growth, economic globalization, non-renewable and renewable energy to investigate their impacts on the CO_2 emission figures of Argentina. In the baseline model, the CO_2 emission figures are modeled as a linear function of the explanatory variables which can be formulated in Eq. (1) below:

$$\textbf{Model 1}: \; lnCO_{2t} = \beta_0 + \beta_1 lnGDP_t + \beta_2 lnNREN_t + \beta_3 lnREN_t + \beta_4 GLO_t + \varepsilon_t \tag{1}$$

where CO_2 represents CO_2 emissions per capita, GDP denotes real economic growth per capita, NREN and REN refer to non-renewable and renewable energy consumptions per capita, respectively, and GLO refers to economic globalization index. We incorporate both non-renewable and renewable energy consumption variables in our model to compare the possible heterogeneous impacts associated with the consumption of alternative energy resources on CO_2 emissions. As per the theoretical underpinnings, the combustion of non-renewable fossil fuels results in the emission of CO_2 into the atmosphere. On the other hand, renewable energy combustion does not release CO_2 into the atmosphere. Besides, it is important to control for non-renewable energy consumption in our model because Argentina has traditionally been fossil fuel-dependent whereby it can be assumed that the changes in Argentina's non-renewable energy consumption levels can effectively explain the variations in the nation's CO_2 emission figures.

The parameter β_0 refers to the intercept to be estimated while the parameters β_1, β_2, β_3, and β_4 are the elasticities of CO_2 emissions that are to be predicted. The subscript t denotes the considered period (1984–2017) while ε denotes the model's error term. Based on the theoretical understanding of economic growth resulting in the employment of energy resources, mostly fossil fuels in the context of Argentina, and therefore stimulating the emission of CO_2, the sign of the elasticity parameter β_1 can be hypothesized to be positive $\left(\text{i.e., } \beta_1 = \frac{\delta CO_2}{\delta GDP} > 0\right)$. On the other hand, since non-renewable and renewable energy consumption has been acknowledged in the literature to boost and inhibit CO_2 emissions, respectively, the signs of the elasticity parameters β_2 and β_3 are assumed to depict positive and negative signs, respectively $\left(\text{i.e., } \beta_2 = \frac{\delta CO_2}{\delta NREN} > 0 \text{ and } \beta_3 = \frac{\delta CO_2}{\delta REN} < 0\right)$. Lastly, since Argentina has persistently globalized its economy and at the same time experienced rising trends in its CO_2 emission figures, the sign of the elasticity parameter β_4 can be expected to be positive as well $\left(\text{i.e., } \beta_4 = \frac{\delta CO_2}{\delta GLO} > 0\right)$.

In order to ascertain the possible joint impacts of energy use and globalization on CO_2 emissions in Argentina, we interact the globalization variable with non-renewable and renewable energy consumption variables and include the interaction terms into our model. The augmented version of the baseline model can be shown in Eq. (2) below:

$$\textbf{Model 2}: \ lnCO_{2t} = \beta_0 + \beta_1 lnGDP_t + \beta_2 lnNREN_t + \beta_3 lnREN_t + \partial_1 (GLO * lnNREN)_t + \partial_2 (GLO * lnREN)_t + \beta_4 GLO_t + \varepsilon_t \quad (2)$$

Based on the theoretical understanding of globalization resulting in greater use of non-renewable energy and therefore boost the CO_2 emission figures, the elasticity parameter ∂_1 can be assumed to be positive (*i.e.*, $\partial_1 > 0$). Conversely, if globalization induces greater use of renewable energy then the CO2 emission figures can be reduced. Consequently, the sign of the elasticity parameter ∂_2 can be assumed to be negative (*i.e.*, $\partial_2 < 0$).

Lastly, as robustness check of the findings to an alternative model specification, we follow the principles of the EKC hypothesis and include the squared term of GDP in our model which can be shown in Eq. (3) below:

$$\textbf{Model 3}: \ lnCO_{2t} = \beta_0 + \beta_1 lnGDP_t + \alpha_1 lnGDPS_t + \beta_2 + \beta_2 lnNREN_t + \beta_3 lnREN_t + \partial_1 (GLO * lnNREN)_t + \partial_2 (GLO * lnREN)_t + \beta_4 GLO_t + \varepsilon_t \quad (3)$$

where the variable GDPS refers to the squared term of the real GDP per capita figures of Argentina. The EKC hypothesis is valid if the signs of the elasticity parameters β_1 and $\alpha_1$are positive and negative, respectively.

3.3. Econometric methodology

3.3.1. Stationary test

It is essential to determine the order of integration by checking the stationarity properties of the variables. The conventional unit-root tests cannot accommodate the possible structural breaks in the data (Kirikkaleli and Adebayo, 2021). Hence, following Xia and Wang (2020), we use the Zivot and Andrews (1992) unit root testing method developed by Zivot and Andrews (1992). This method is robust to handling structural break concerns in the data. Considering at least one structural break in the data, the associated models are shown as: Model A:

$$\text{Model A}: \ \Delta y = \sigma + \hat{u} y_{t-1} + \beta t + \gamma DU_t + \sum_{j=i}^{t} d_j \Delta y_{t-j} + \varepsilon_t \quad (4)$$

$$\text{Model B}: \ \Delta y = \sigma + \hat{u} y_{t-1} + \beta t + \theta DT_t + \sum_{j=i}^{t} d_j \Delta y_{t-j} + \varepsilon_t \quad (5)$$

$$\text{Model C}: \ \Delta y = \sigma + \hat{u} y_{t-1} + \beta t + \theta DT_t \gamma DU_t + \sum_{j=i}^{t} d_j \Delta y_{t-j} + \varepsilon_t \quad (6)$$

where; DU_t denotes the mean shift of the dummy variable, which occurs at possible break-date (TB); DT_t denotes the trend shift of the corresponding variable used. Formally,

$$DU_t = \begin{cases} 1 \ldots\ldots\ldots\ldots \text{if } t > TB \\ 0 \ldots\ldots\ldots\ldots \text{if } t < TB \end{cases} \quad \text{and} \quad DU_t = \begin{cases} t - TB \ldots\ldots \text{if } t > TB \\ 0 \ldots\ldots\ldots\ldots \text{if } t < TB \end{cases} \quad (7)$$

Zivot–Andrews unit root test has three options in respect of allowing the structural break to occur in the intercept (Model A), trend (Model B), and both intercept and trend (Model C). In the context of this study, Model C is used which predicts test statistics under the null hypothesis of non-stationary of the series against the alternative hypothesis of stationarity of the series with a single break occurring at an unidentified point in time. The unit root analysis is followed by the cointegration analysis.

3.3.2. Maki cointegration

A cointegration test is conducted to assess the long-run relationships of the considered series. The conventional cointegration test provides erroneous estimates due to failing to consider the structural breaks within the estimation process. However, Hatemi-J (2008), Westerlund and Edgerton (2007), Gregory and Hansen (1996) are some of the cointegration techniques that have taken into account with one or two structural break(s) into the estimation. Besides, considering the unpredictability of economic and financial series, accounting for multiple structural breaks in the data is preferable. As a result, following Iorember et al. (2021), this study employed a more advanced cointegration method introduced by Maki (2012). The Maki cointegration method is capable of capturing multiple structural breaks (up to a maximum of five) in the data within the estimation process. Moreover, this technique is appropriate when all the series are stationary at I(1). The different models under the Maki cointegration test, depending on the assumption of the locations of the structural breaks, is defined in Eqs. (8), (9), (10), and (11) as follows:

Model A: For level shift:

$$Y_t = \rho + \sum_{i=1}^{k} \rho_i D_{i,t} + \theta' Z_t + \varepsilon_t \quad (8)$$

Model B: For level shift with trend

$$Y_t = \rho + \sum_{i=1}^{k} \rho_i D_{i,t} + \theta' Z_t + \sum_{i=1}^{k} \theta' Z_t D_{i,t} + \varepsilon_t \quad (9)$$

Model C: For regime shifts

$$Y_t = \rho + \sum_{i=1}^{k} \rho_i D_{i,t} + \theta' Z_t + \sigma t + \sum_{i=1}^{k} \theta' Z_t D_{i,t} + \varepsilon_t \quad (10)$$

Model D: For trend and regime shifts

$$Y_t = \rho + \sum_{i=1}^{k} \rho_i D_{i,t} + \theta' Z_t + \sigma t + \sum_{i=1}^{k} \sigma' D_{i,t} + \sum_{i=1}^{k} \theta' Z_t D_{i,t} + \varepsilon_t \quad (11)$$

where Y_t depicts CO_2 and Z_t represents the explanatory variables (GDP, NREN, REN, and GLO). The confirmation of the cointegration among the variables allows us to predict the long-run elasticities of CO_2 emissions.

3.3.3. The autoregressive distributive lag (ARDL) model

Due is advantageous features, the ARDL approach is appropriate for estimating both the short- and long-run elasticities, suitable for estimating data sets with small sample sizes, and selecting different lag lengths to address the endogeneity and serial correlation problems. The ARDL approach has been extensively used in preceding studies that have scrutinized the macroeconomic determinants of CO_2 emissions (Koc and Bulus, 2020; Pata and Caglar, 2021). Besides, this study also uses the ARDL bounds testing approach as a robustness test for the Maki cointegration test. The short and long elasticities, in the context of the baseline model (Eq. (1)) are generated from Eq. (12) given below:

$$\begin{aligned}\Delta CO_{2t} = \theta_0 + \sum_{i=1}^{t}\theta_1\Delta CO_{2t-i} + \sum_{i=1}^{t}\theta_2\Delta GDP_{t-i} + \sum_{i=1}^{t}\theta_3\Delta NREN_{t-i} \\ + \sum_{i=1}^{t}\theta_4\Delta REN_{t-i} + \sum_{i=1}^{t}\theta_5\Delta GLO_{t-i} \\ + \beta_1 CO_{2t-1} + \beta_2 GDP_{t-1} + \beta_3 NREN_{t-1} + \beta_4 REN_{t-1} \\ + \beta_5 GLO_{t-1} + ECT_{t-1} \\ + \varepsilon_t \qquad (12)\end{aligned}$$

where: θ and β denote the short and long-run elasticity parameters of CO_2 emissions, respectively. Δ and ε indicate the first difference operator and error-term, respectively. However, to verify the validity of the ARDL models considered in this study, several diagnostic tests are conducted. Furthermore, as a robustness check of the long-run elasticity estimates, the Fully-Modified Ordinary Least Squares (FMOLS) estimator of Phillips and Hansen (1990) and the Dynamic Ordinary Least Squares (DOLS) estimator of Stock and Watson (1993) are also employed in this study. Both these estimators allow asymptotic coherence by considering the serial correlation effect and are appropriate for handling cointegrated variables. Finally, the causality analysis is performed.

3.3.4. Gradual shift causality

Nazlioglu et al. (2016) constructed the gradual shift causality method which is built on the approach of Toda and Yamamoto (1995), which was constructed of the vector autoregressive (VAR) estimation in levels. Nazlioglu et al. (2016) employed the Fourier approximation and Toda–Yamamoto causality test to capture the causality between the CO_2 and its regressors by considering a structural change (smooth and gradual shifts). Hence, following Zhang et al. (2021), the gradual shift causality method is used in this study which can be defined as follows:

$$y_t = \sigma\,(t) + \beta_1 y_{t-1} + \cdots + \beta_{p+dmax} y_{t-(p+dmax)} + \varepsilon_t \qquad (13)$$

where: y_t stands for CO_2, GDP, NREN, REN, and GLO; σ refers to the intercept; β denotes the coefficient matrices; ε depicts error term. Eq. (13) indicates the VAR (p + d) model. Eq. (14) explains the Fourier approximation process which captures the structural shifts:

$$\sigma\,(t) = \sigma_0 + \gamma_1 \sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 \cos\left(\frac{2\pi kt}{T}\right) \qquad (14)$$

where: k is the frequency of the approximation. By substituting Eq. (14) into Eq. (13), the Fourier Toda–Yamamoto causality is defined in Eq. (15) as:

$$\begin{aligned}y_t = \sigma_0 + \gamma_1 \sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 \cos\left(\frac{2\pi kt}{T}\right) \\ + \beta_1 y_{t-1} + \cdots + \beta_{p+d} y_{t-(p+d)} \\ + \varepsilon_t \qquad (15)\end{aligned}$$

Fig. 2 outlines the econometric methodology considered in this study.

Table 3
Descriptive statistics.

Variables	CO2	NREN	GDP	GLO	REN
Mean	0.588316	9.683822	3.911306	1.762872	7.376628
Median	0.578618	9.632892	3.888942	1.783224	7.637322
Maximum	0.671475	9.916882	4.036761	1.853171	8.055123
Minimum	0.518660	9.505820	3.795582	1.670984	5.174332
Std. Dev.	0.042605	0.123634	0.066922	0.064151	0.778846
Skewness	0.450014	0.710772	0.579492	−0.130525	−1.579252
Kurtosis	2.016271	2.092538	2.112955	1.277000	2.143092
Jarque–Bera	3.629624	4.112329	4.348936	6.200289	6.322912
Probability	0.162869	0.137213	0.113669	0.045043	0.036120
Observations	49	49	49	49	49

Table 4
Zivot and Andrews unit root test.

	At level I(0)		First difference I(1)		Order of integration
	Intercept & Trend	Break-date	Intercept & Trend	Break date	
GDP	−3.535	2008	−6.769*	2003	I(1)
CO_2	−4.313	2006	−6.500*	2004	I(1)
NREN	−3.863	2005	−7.443*	2003	I(1)
GLO	−4.407	1993	−5.670*	1991	I(1)
REN	−4.158	1979	−9.668*	1992	I(1)

Note: * denotes statistical significance at 1% level of significance.

4. Findings and discussions

This section begins by providing the descriptive statistics of the variables which are reported in Table 3. It can be seen that the variables CO2, NREN, and GDP are positively skewed while GLO and REN are negatively skewed. Besides, the kurtosis values for all variables are below three which implies that these variables are platykurtic. Moreover, the probability values of the Jarque–Bera statistics denote that all the variables apart from GLO and REN are normally distributed.

Table 4 reports the findings from the Zivot–Andrews unit root analysis. The statistical significance, at 1% level, of the predicted test statistics, affirm that the variables are commonly integrated at the first difference, I(1). Besides, the locations of the structural breaks for the respective variables are also identified: CO_2 (2004), GDP (2003), NREN (2003), REN (1992), and GLO (1991). The confirmation of the stationarity of the variables allows us to proceed to the cointegration analysis.

Table 5 reports the findings from the Maki cointegration analysis. Although this method identifies a maximum of five structural breaks for each model, we purposively limit the number of structural breaks to be identified to two considering the finite sample properties of our data. Besides, the identified structural break dates for CO_2 are used to construct structural break dummies and controlled for within the regression analysis. The statistical significance of the test statistics, at 5% significance level, affirms the existence of at least one cointegrating equation in all three models. This implies that there are long-run associations amid CO_2 emissions, non-renewable energy consumption, renewable energy consumption, economic growth, and globalization in the context of Argentina. Furthermore, as a robustness check, the ARDL bounds test is also applied to evaluate cointegration among these variables. Table 6 reports the findings from the bounds test. It is evidenced that for all three models the value of the estimated F-statistic is larger than the upper and lower bounds critical values at the 1% level of significance. Therefore, the statistical significance of the F-statistics certifies the existence of

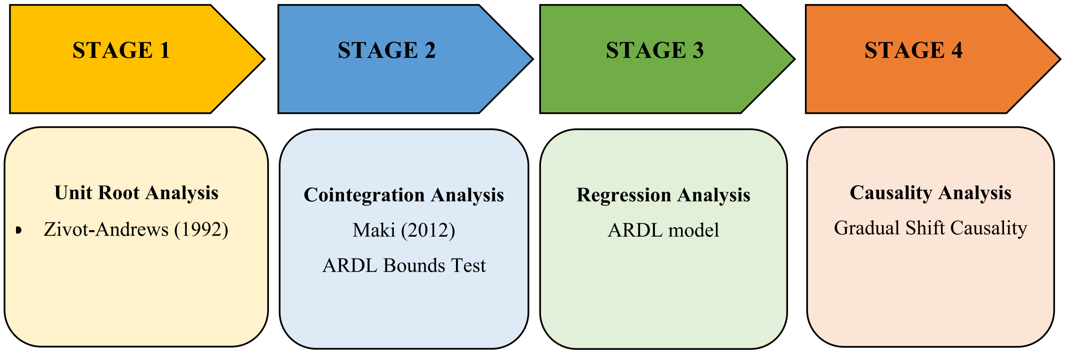

Fig. 2. The econometric methodology.

Table 5
Maki co-integration test.

Model	Specification	Test statistic	Critical values at 5%	Break years
1	CO_2=f(GDP, NREN, REN, GLO)	−7.212510**	−6.911	1997, 1979
2	CO_2=f(GDP, NREN, REN, GLO, GLO*NREN, GLO*REN)	−7.921253**	−7.638	1997, 1980
3	CO_2=f(GDP, GDPS, NREN, REN, GLO, GLO*NREN, GLO*REN)	−8.211211**	−9.482	1997, 1979

Note: ** denotes statistical significance at 5% significance level; The test statistics are predicted using 5000 bootstrapped replications

cointegrating relationships between the variables of concern. The regression analysis follows the cointegration analysis.

Table 7 also reports the elasticity outcomes from the ARDL analysis both for the long and short run. In the context of the baseline model (Model 1) it can be seen that economic growth positively influences the CO_2 emission figures of Argentina both in the short- and long run. A rise in the GDP per capita level by 1% is seen to boost CO_2 emissions per capita by 0.473% and 0.306% in the short- and long-run, respectively, *ceteris paribus*. The results portray two key aspects of the economic growth-CO_2 emissions nexus in the context of Argentina. First, economic growth is detrimental to environmental quality. Secondly, the long-run adverse environmental impacts associated with economic growth are evidence to be relatively lower than that in the short run. Overall, it can be said that the growth of the Argentine economy is achieved at the expense of environmental degradation. These findings are consistent with results documented in the studies by Ayobamiji and Kalmaz (2020) for Nigeria; Adebayo and Odugbesan (2020) for South Africa; Beşer and Hızarcı Beşer (2017) for Turkey; Godil et al. (2021) for Pakistan.

The other relevant findings reveal that non-renewable energy consumption triggers CO_2 emissions while renewable energy consumption inhibits the emissions both in the short- and long run. The corresponding elasticity estimates reveal that a 1% rise in the non-renewable energy consumption per capita level triggers CO_2 emissions per capita levels by 0.215% and 0.460% in the short- and long-run respectively, *ceteris paribus*. On the other hand, a 1% rise in the renewable energy consumption per capita figures is associated with a decline in the emission levels by 0.008% and 0.006% in the short- and long-run respectively, *ceteris paribus*. Hence, it can be said that replacing non-renewable energy use with consumption of renewable alternatives (synonymous with a decline in the fossil fuel dependency level) assists in improving the environmental quality in Argentina. Moreover, the elasticity estimates also point out that the CO_2 emission figures of Argentina are pretty inelastic to positive shocks to the renewable energy consumption levels; whereas, CO_2 emissions are relatively more elastic to positive shocks to the non-renewable energy consumption figures in the context of Argentina. On the other hand, it is also evidenced that the adverse environmental impacts associated with non-renewable energy use persistently increases with time. On the other hand, the favorable environmental impacts of renewable energy use tend to increase over time. Hence, these findings further suggest that reducing fossil fuel dependency can be considered as a credible means of restricting CO_2 emissions in Argentina. Similar long-run findings were also reported in the studies by Pata (2021) for the United States, Zafar et al. (2019b) for emerging economies, and Bilgili et al. (2016) for OECD countries.

As far as the impacts of globalization are concerned, the baseline model results reveal that globalization actually helps Argentina to improve its environmental quality. This finding is inconsistent with the assumption of globalization causing higher CO_2 emissions in Argentina given that the nation's globalization index and CO_2 emissions levels have both risen over the years. The corresponding elasticity estimates show that a 1% rise in the globalization index is associated with a decline in the CO_2 emissions per capita figures by 0.414% in the short run and 0.559% in the long run. This finding is in line with the findings documented in the study by Shahbaz et al. (2017) for the case of China. To further explore the reason behind such a paradoxical finding, we also scrutinize the joint impacts of globalization and energy consumption. In the context of Model 2, it is evidenced

Table 6
Bounds test.

Model	Specification	F-statistic	Critical value at 1%		Critical value at 5%		Critical value at 10%	
			LB	UB	LB	UB	LB	UB
1	CO_2=f(GDP, NREN, REN, GLO)	6.12*						
2	CO_2=f(GDP, NREN, REN, GLO, GLO*NREN, GLO*REN)	6.23*	3.74	5.06	3.10	4.01	2.45	3.52
4	CO_2=f(GDP, GDPS, NREN, REN, GLO, GLO*NREN, GLO*REN)	6.12*						

Note: * denotes statistical significance at 1% significance level; LB and UB denote lower bound and upper bound critical values, respectively.

Table 7
ARDL short- and long-run results.

Regressors	Model 1	Model 2	Model 3
Short-run results			
GDP	0.473* (0.121)	0.426* (0.135)	0.319* (0.101)
GDPS	–	–	−0.040 (0.032)
NREN	0.215** (0.101)	0.275* (0.120)	0.328* (0.145)
REN	−0.006* (0.002)	0.007* (0.002)	0.006** (0.003)
GLO	−0.414* (0.086)	−0.393* (0.093)	−0.300* (0.085)
(GLO*NREN)	–	0.120 (0.090)	0.132 (0.110)
(GLO*REN)	–	−0.012 (0.080)	−0.013 (0.095)
GDPS	–	–	–
D(BY1)	1.230** (0.595)	1.440** (0.711)	1.513* (0.511)
D(BY2)	1.780* (0.239)	1.780* (0.239)	1.820* (0.310)
Long-run results			
GDP	0.306* (0.135)	0.419* (0.120)	0.300* (0.095)
GDPS	–	–	−0.032* (0.010)
NREN	0.460** (0.177)	0.580* (0.193)	0.535* (0.160)
REN	−0.008* (0.000)	−0.011* (0.003)	−0.013* (0.004)
GLO	−0.559** (0.261)	−0.490* (0.122)	−0.456* (0.105)
(GLO*NREN)	–	0.020** (0.009)	0.025** (0.012)
(GLO*REN)	–	−0.025** (0.012)	−0.031** (0.015)
GDPS	–	–	–
D(BY1)	1.021** (0.495)	1.532** (0.741)	1.610** (0.822)
D(BY2)	2.220* (0.951)	1.980* (0.210)	2.110* (0.325)
Constant	−2.674(1.780)	−3.176**(1.518)	−3.365*(1.500)
Diagnostics			
Adj. R2	0.892	0.911	0.915
ECT_{t-1}	−0.738* (0.246)	−0.750* (0.219)	−0.783* (0.235)
LM test	0.063 (0.661)	0.113 (0.756)	0.106 (0.626)
Ramsey-Reset test	0.041 (0.547)	0.442 (0.701)	0.315 (0.765)
Jarque–Bera test	0.116 (0.453)	0.231 (0.795)	0.372 (0.481)
White test	1.793 (0.175)	0.495 (0.480)	0.137 (0.666)

Note: * and ** denote statistical significance at 1% and 5% level of significance, respectively; the optimal lag selection is based on the Akaike Information Criterion; the standard errors are reported within the parentheses; D(BY1) and D(BY2) refer to the structural break dummy variables identified from the Maki cointegration analysis for the respective models.

Table 8
FMOLS and DOLS results.

Estimator	Model 1		Model 2		Model 3	
	FMOLS	DOLS	FMOLS	DOLS	FMOLS	DOLS
GDP	0.382* (0.090)	0.3824** (0.185)	0.306* (0.081)	0.363* (0.112)	0.480* (0.092)	0.437* (0.106)
GDPS					−0.031* (0.010)	−0.035* (0.009)
NREN	0.593* (0.112)	0.596* (0.164)	0.622* (0.210)	0.659* (0.182)	0.637* (0.154)	0.654* (0.114)
REN	−0.008* (0.002)	−0.009* (0.003)	−0.010** (0.004)	−0.012* (0.004)	−0.011** (0.006)	0.012** (0.006)
GLO	−0.501** (0.251)	−0.533** (0.261)	−0.529* (0.173)	−0.502* (0.187)	−0.527* (0.156)	−0.530* (0.139)
(GLO*NREN)			0.022* (0.008)	0.021** (0.011)	0.019* (0.005)	0.018* (0.004)
(GLO*REN)			−0.031* (0.012)	−0.033* (0.012)	−0.039* (0.015)	−0.038* (0.014)
D(BY1)	1.497* (0.307)	1.210* (0.295)	1.820* (0.263)	1.919* (0.672)	1.309* (0.184)	1.421* (0.262)
D(BY2)	2.036* (0.310)	2.092* (0.315)	2.033* (0.278)	2.497* (0.290)	2.132* (0.497)	2.345* (0.334)
Constant	−2.921* (0.534)	−2.027* (0.509)	−3.651* (0.847)	−3.370* (0.914)	−3.004* (1.083)	−3.223* (1.048)
Adj. R2	0.793	0.847	0.805	0.874	0.823	0.889

Note: * and ** denote statistical significance at 1% and 5% levels of significance, respectively; the standard errors are reported within the parentheses; D(BY1) and D(BY2) refer to the structural break dummy variables identified from the Maki cointegration analysis for the respective models.

that globalization and non-renewable energy consumption jointly boost the long-run CO_2 emissions per capita figures of Argentina. On the other hand, globalization and renewable energy consumption are found to jointly curb CO_2 emissions. The positive and negative signs of the long-run elasticity parameters attached to the interaction terms (GLO*NREN) and (GLO*REN), respectively, affirm these claims. Therefore, it can be said that non-renewable energy, to some extent, neutralizes the positive environmental impacts associated with globalization while renewable energy consumption enhances the positive environmental impacts of globalization in Argentina. As a result, reducing fossil fuel dependency is once again deemed necessary for improving the overall quality of the environment in Argentina. Lastly, to check for the robustness of the elasticity estimates using an alternative model specification, we include the squared term of GDP in our model. In this regard, the elasticity estimates in the context of Model 3 reveal that the EKC hypothesis holds in the long run but not in the short run. The negative signs of the statistically significant elasticity parameters attached to the squared term of GDP verify the inverted U-shaped economic growth-CO_2 emissions nexus to authenticate the EKC hypothesis in the long run. Therefore, it can be said that economic growth initially degrades the environment while improving it later on. This finding is in line with that highlighted in the study by Ali et al. (2020) for Pakistan.

Now referring to the results of the diagnostic tests, it can be said that the adjusted R-squared values are high which imply that around 89.2%–91.5% of the variations in the CO_2 emission figures of Argentina can be explained by changes in levels of economic growth, energy consumption (both renewable and non-renewable), and globalization. On the other hand, the negative sign and statistical significance of the lagged error-correction terms (ECT_{t-1}) imply that any short-run disequilibrium converges to the long-run equilibrium level at a rate of 73.8%–78.3%. Besides, the diagnostic test findings also reveal that three models are free from model misspecification issues, serial correlation problems, heteroscedasticity concerns, non-normality issues. The statistical insignificance of the predicted test statistics from the LM test, Ramsey-Reset test, Jarque–Bera test, and White test affirm these claims. Furthermore, the CUSUM and CUSUMSQ plots (shown in Figs. 3, 4, and 5) for all models verify the stability of the parameters concerning the respective models.

For further robustness check of the long-run elasticity estimates from the ARDL analysis, the models are re-estimated using the FMOLS and DOLS estimators. The elasticity estimates from the FMOLS and DOLS analyses (shown in Table 8) are similar, in terms of the predicted signs, to the ARDL elasticity estimates (shown in Table 7). Thus, the robustness of our findings is verified across alternative regression techniques.

Finally, the causal relationships between the variables are ascertained by employing the gradual shift causality analysis. Table 9 reports the causality estimates. Concerning the causal relationships between economic growth and CO_2 emissions, the results reveal that CO_2 emissions causally influence the economic growth level in Argentina. This implies that Argentina's economic sustainability is conditional on the quality of its environment. On the other hand, a unidirectional causality is evidenced to stem from renewable energy consumption to CO_2 emissions which certify the corresponding elasticity estimates to emphasize the promotion of renewable energy use for environmental well-being in Argentina. Similarly, a unidirectional causality from non-renewable energy consumption to CO_2 emission is also revealed which also supports the corresponding elasticity estimates to highlight the pertinence of implementing policies for reducing non-renewable energy use and curbing CO_2 emissions in Argentina. Lastly, no causal relationship between globalization and CO_2 emissions in the context of Argentina could be established

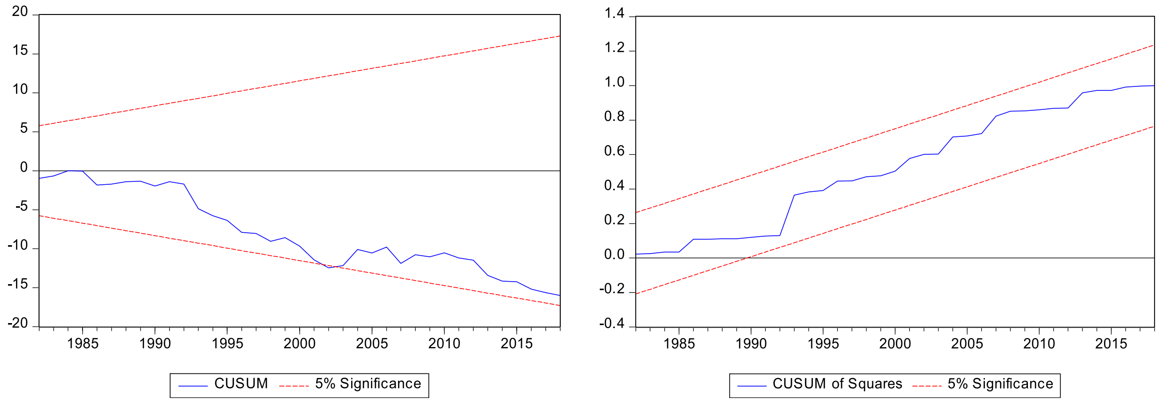

Fig. 3. The CUSUM and CUSUMSQ plots for Model 1.

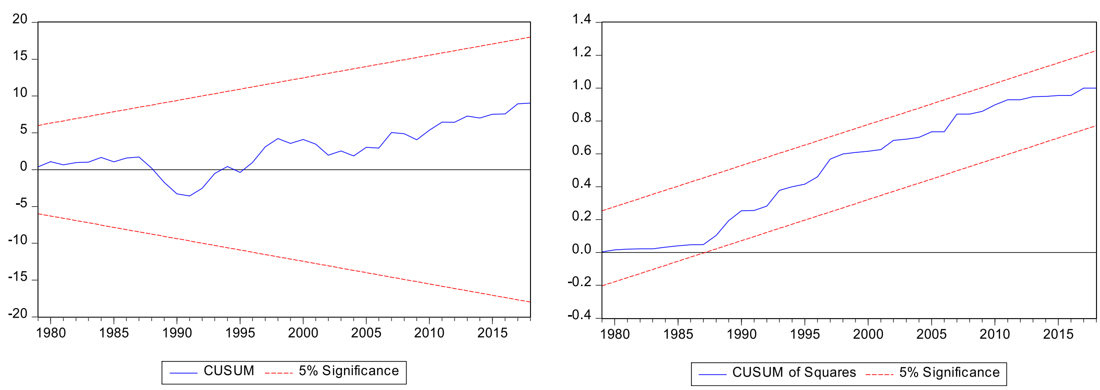

Fig. 4. The CUSUM and CUSUMSQ plots for Model 2.

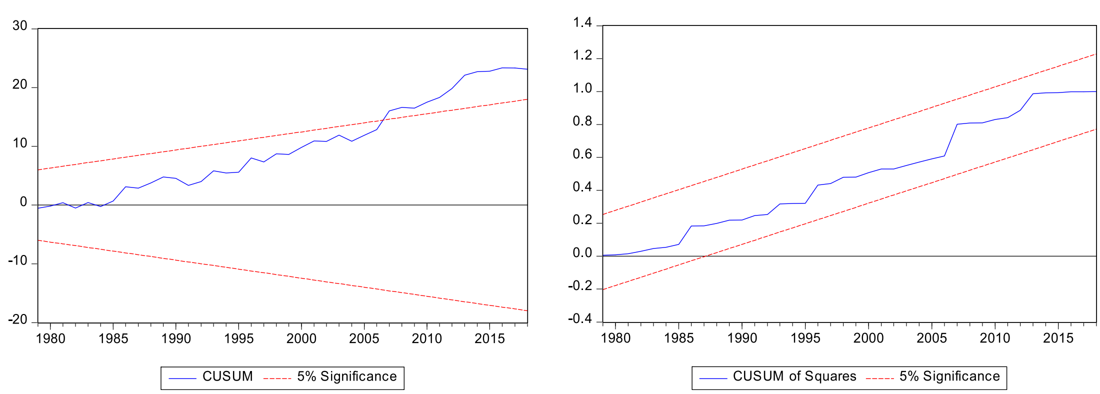

Fig. 5. The CUSUM and CUSUMSQ plots for Model 3.

from the causality estimates. This indicates that the causal relationship between these variables could be determined by some other variable like the energy consumption level.

5. Conclusion and policy pathways

Environmental pollution has become a major subject of discussion across the globe. Consequently, the world nations are trying to adopt and implement credible policies which can help to attain

Table 9
Gradual shift causality test.

Causality path	Wald-stat	No of Fourier	P-Value	Decision
GDP→CO_2	6.709819	4	0.459706	Do not reject Ho
CO_2→ GDP	12.98024	4	0.072591	Reject Ho
REN→ CO_2	11.22142	3	0.067251	Reject Ho
CO_2→REN	2.240622	3	0.852400	Do not reject Ho
NREN→ CO_2	15.82142	3	0.025691	Reject Ho
CO_2→ NREN	7.221231	3	0.255128	Do not reject Ho
GLO→ CO_2	2.722745	2	0.909412	Do not reject Ho
CO_2→ GLO	2.435213	2	0.931896	Do not reject Ho

Note: Significance levels of 1% and 5% are represented by * and **, respectively. → depict causality path.

economic growth without degrading the environment. The pertinence of controlling environmental pollution is of paramount importance for the emerging economies in particular since these nations are expected to make significant contributions to the global output and, therefore, are also likely to account for a major share of the global GHG emissions. Against this backdrop, this study investigated the effects of renewable energy consumption, non-renewable energy consumption, globalization, and economic growth on the CO_2 emission figures of Argentina using annual data from 1970 to 2018. Controlling for the structural break issues in the data, the overall results reveal long-run cointegrating relationships between the variables of concern. Besides, the elasticity estimates, in a nutshell, revealed that renewable energy consumption and globalization inhibit CO_2 emissions in Argentina while non-renewable energy consumption boosts the emission figures. Moreover, globalization and non-renewable energy use were jointly found to trigger CO_2 emissions in the long run only. In contrast, globalization and renewable energy consumption were found to jointly reduce CO_2 emissions in the long run only. Hence, these joint impacts concerning globalization and energy consumption indicate that the favorable environmental impacts of globalization in Argentina are conditional on the phasing out of the nation's fossil fuel dependency. Furthermore, the EKC hypothesis was also verified for Argentina. Lastly, the causality analysis, in almost all cases, led to outcomes that provided support to the corresponding elasticity estimates. In line with these findings, several policy-level suggestions can be put forward for Argentina to attain economic and environmental welfare in tandem.

First, it is critically important for Argentina to reduce its monotonic reliance on fossil fuels for meeting the domestic energy demand. Although the Argentine government has decided to upscale investments for renewable energy development within the country, supporting policies have to be adopted and implemented to overcome the traditional barriers that have impeded renewable energy adoption in Argentina. Besides, it is also important for Argentina to significantly reduce its fossil fuel imports and try to utilize the indigenous renewable and relatively cleaner energy resources to bridge the local energy demand. Secondly, although globalization is found to be contributing to environmental prosperity in Argentina, it is essential to ensure that the globalization-induced rise in energy demand is met by renewable energy resources. In this regard, Argentina can look to trade renewable energy from its neighboring countries whereby the positive environmental outcomes associated with trade globalization can be enhanced further. Simultaneously, the Argentine government should also think of attracting FDI for the development of its renewable energy sector. It can be expected that financial globalization-induced FDI inflows can result in technological spillover which, in turn, can relieve the technological constraints that have inhibited renewable energy adoption in Argentina. Lastly, it is imperative for Argentina to catalyze its economic growth rates, using renewable and cleaner energy resources in particular, so that the nation can reach the threshold level of economic growth beyond which economic and environmental development can be simultaneously ensured. Hence, it is once again recommended that the nation reduces its fossil fuel dependency and transform its production processes in an environmentally friendly manner. The implementation of these policies can be expected to assist Argentina in complying with its environmental protection commitments pledged under the Paris Climate change agreement.

Unavailability of relevant data has limited the period of the study. Besides, data limitation also restricted us from including other key macroeconomic variables in our models. In future, this study can be extended to assess the impacts of different components of globalization on Argentina's CO_2 emission figures and other indicators of environmental quality.

CRediT authorship contribution statement

Li Yuping: Project administration. **Muhammad Ramzan:** Conceptualization, Supervision, Formal analysis, Funding acquisition, Writing - review & editing. **Li Xincheng:** Project administration. **Muntasir Murshed:** Revision, Data curation, Investigation, Editing. **Abraham Ayobamiji Awosusi:** Data curation, Investigation. **Sununu Ibrahim BAH:** Methodology, Resources. **Tomiwa Sunday Adebayo:** Formal analysis, Software, Validation.

Declaration of competing interest

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

Ethical approval

This study follows all ethical practices during writing.

Funding

This study received no specific financial support.

Transparency

The authors confirms that the manuscript is an honest, accurate, and transparent account of the study was reported; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Availability of data

Data is readily available at https://data.worldbank.org/country/argentina.

Appendix

See Table 1.

Table 1
Summary of empirical literature.

Author (s)	Period	Variables	Country (s)	Methodology	Results
Lean and Smyth (2010)	1980–2006	GDP and CO_2	Five ASEAN countries	Johansen Fisher panel cointegration test, DOLS, Panel Granger causality,	EC→ GDP CO_2 → GDP CO_2 ↔ EC
Wang et al. (2011)	1995–2007	GDPpc, EC, CO_2	China	Panel Vector Error Correction model, Panel Granger Causality test	CO_2 ↔ EC GDPpc ↔ EC
Odhiambo (2012)	1980–2004	GDP, EC, CO_2	South Africa	ARDL Bounds test	GDP→ CO_2 EC →GDP EC→ CO_2
Saboori et al. (2012)	1980–2009	GDP and CO_2	Malaysia	ARDL Bounds Testing	CO_2 → GDP
Hossain (2012)	1960–2009	CO_2, EC, GDP, T.O, and UR	Japan	ARDL Bounds Testing	EC→ CO_2 T.O→ CO_2 T.O→EC EC →GDP GDP→TO
Ozturk and Acaravci (2013)	1960–2007	CO_2, EC, GDP, T.O, FD	Turkey	ARDL Bounds Testing	FD ↔ CO_2
Farhani et al. (2014)	1971–2008.	CO_2, EC, GDP, FD	Tunisia	ARDL Bounds Testing, Granger causality tests	FD→ CO_2
Alshehry and Belloumi (2015)	1971–2010	GDP, EC, CO_2, PR	Saudi Arabia	The Johansen's cointegration test, Granger causality tests	GDP ↔ CO_2 EC →GDP PR →GDP PR → CO_2 EC → CO_2
Al-Mulali et al. (2015)	1980–2010	GDP, EC, CO_2	19 Selected Countries Latin America &Caribbean countries	Panel FMOLS, Granger causality test,	FD ↔ CO_2
Kasman and Duman (2015)	1992–2010	CO_2, EC, GDP, T.O, and UR	14 European Countries	Panel Cointegration, Panel FMOLS, Panel Granger Causality test	EC→ CO_2 T.O→ CO_2 UR→EC EC →GDP
Ben Jebli and Ben Youssef (2015)	1980–2009	CO_2, EC, NRE, GDP, O	Tunisia	ARDL, Granger Causality test	EC →RE GDP →RE CO_2 →RE EC →RE
Saidi and Ben Mbarek (2016)	1990–2013	CO_2, EC, GDP, L, and K	9Developing Countries	Panel DOLS, Panel FMOLS, Panel Granger Causality test	EC →GDP L ↔ K CO_2↔ K L → CO_2
Rafindadi (2016)	1971–2011	EC, FD, GDP, T.O	Nigeria	ARDL bounds, Bayer and Hanck cointegration, VECM Granger causality.	FD→EC
Saidi and Hammami (2016)	1990–2012	CO_2, EC, GDP, FDI, and K	58 countries	Generalized Method of Moments (GMM)	EC ↔ CO_2 CO2 → GDP
Ali et al. (2017)	1971–2012	GDP, EC, T.O, FDI, CO_2	Malaysia	ARDL Bounds Test DOLS, Granger causality test.	CO_2 ↔ EC GDP→ CO_2 FDI→ CO_2 T.O→ CO_2
Aye and Edoja (2017)	1971–2013	GDP, EC, POP, FD, CO_2	31developing countries	A dynamic panel threshold model	GDP ↔ CO_2 EC → CO_2 FD↔ CO_2
Destek and Aslan (2017)	1980–2012	GDP, NREC, EC	17 emerging countries	Bootstrap panel causality	EC→GDP(PER) EC ↔ GDP
Koengkan (2017)	1980–2014	GDP, EC, UR	21 Latin American and Caribbean countries	Panel Data Vector Autoregressive (PVAR)	UR ↔EC GDP→EC
Nazir et al. (2018)	1970–2016	GDPpc, T.O, FD, EC, FDI	Pakistan	ARDL Bounds Test, Granger causality test.	CO_2 ↔ EC GDP→ CO_2 FDI→ CO_2 T.O→ CO_2 FD → CO_2
Faisal et al. (2018)	1965–2013.	GDP, UR, EC, T.O	Iceland	A.R.D.L. bounds testing, Granger causality	UR→EC
Pata (2018)	1974–2014.	CO_2, UR, FD, REC, HEC, AEC.	Turkey	ARDL, FMOLS and canonical cointegrating regression (CCR)	Renewable energy consumption does not have a reducing effect on CO_2 emissions in the long-run.
Chen et al. (2019)	1980–2014	CO_2, GDP, NREC, EC, T.O	China	ARDL, Granger causality	CO_2 ↔ EC T.O ↔ EC NREC ↔ EC
Aydoğan and Vardar (2020)	1990–2014	GDP, NREC, REC, Agri	E7 countries	FMOLS and DOLS, panel Granger causality	CO_2 ↔ NREC
Koengkan and Fuinhas (2020a,b)	1980–2014	GDP, CO_2, NREC, EC, UR	Argentina, Brazil, Paraguay, Uruguay, and Venezuela	Panel ARDL	NREC↔GDP CO_2↔EC REC→UR
Koengkan et al. (2020)	1980–2014	CO_2, GDP, EC, F.O, AGRI	MERCOSUR countries	Panel ARDL	FD → CO_2

Note: GDP = Economic growth, CO_2 = Carbon emission, EC = energy consumption, NREC = Non-renewable energy consumption, AGRI = Agriculture, T.O = Trade openness, FD = Financial Development, UR = urbanization, FDI = Foreign Direct Investment, POP = population, K = Capital, L = labor.

References

Acheampong, A.O., 2018. Economic growth, CO2 emissions and energy consumption: what causes what and where? Energy Econ. 74, 677–692.

Adebayo, T.S., Awosusi, A.A., Adeshola, I., 2020. Determinants of co2 emissions in emerging markets: An empirical evidence from mint economies. Int. J. Renew. Energy Dev. http://dx.doi.org/10.14710/ijred.2020.31321.

Adebayo, T.S., Odugbesan, J.A., 2020. Modeling CO2 emissions in South Africa: empirical evidence from ARDL based bounds and wavelet coherence techniques. Environ. Sci. Pollut. Res. http://dx.doi.org/10.1007/s11356-020-11442-3.

Adebayo, T.S., Ramzan, M., Iqbal, H.A., Awosusi, A.A., Akinsola, G.D., 2021. The environmental sustainability effects of financial development and urbanization in Latin American countries. Environ. Sci. Pollut. Res. 1–14.

Al-Mulali, U., Tang, C.F., Ozturk, I., 2015. Estimating the Environment Kuznets Curve hypothesis: Evidence from Latin America and the Caribbean countries. Renew. Sustain. Energy Rev. 50, 918–924. http://dx.doi.org/10.1016/j.rser.2015.05.017.

Ali, W., Abdullah, A., Azam, M., 2017. Re-visiting the environmental Kuznets curve hypothesis for Malaysia: Fresh evidence from ARDL bounds testing approach. Renew. Sustain. Energy Rev. 77, 990–1000. http://dx.doi.org/10.1016/j.rser.2016.11.236.

Ali, M.U., Gong, Z., Ali, M.U., Wu, X., Yao, C., 2020. Fossil energy consumption, economic development, inward FDI impact on CO2 emissions in Pakistan: Testing EKC hypothesis through ARDL model. Int. J. Finance Econ. http://dx.doi.org/10.1002/ijfe.1958.

Allard, A., Takman, J., Uddin, G.S., Ahmed, A., 2018. The N-shaped environmental Kuznets curve: an empirical evaluation using a panel quantile regression approach. Environ. Sci. Pollut. Res. 25, 5848–5861. http://dx.doi.org/10.1007/s11356-017-0907-0.

Alshehry, A.S., Belloumi, M., 2015. Energy consumption, carbon dioxide emissions and economic growth: The case of Saudi Arabia. Renew. Sustain. Energy Rev. 41, 237–247. http://dx.doi.org/10.1016/j.rser.2014.08.004.

Aydoğan, B., Vardar, G., 2020. Evaluating the role of renewable energy, economic growth and agriculture on CO 2 emission in E7 countries. Int. J. Sustain. Energy 39, 335–348. http://dx.doi.org/10.1080/14786451.2019.1686380.

Aye, G.C., Edoja, P.E., 2017. Effect of economic growth on CO2 emission in developing countries: Evidence from a dynamic panel threshold model. Cogent Economics & Finance 5 (1), 1379239.

Ayobamiji, A.A., Kalmaz, D.B., 2020. Reinvestigating the determinants of environmental degradation in Nigeria. Int. J. Econ. Policy Emerg. Econ. 13 (52), http://dx.doi.org/10.1504/ijepee.2020.106680.

Beşer, M.K., Hızarcı Beşer, B., 2017. The relationship between Energy Consumption, CO2 emissions and GDP per Capita: A revisit of the evidence from Turkey. Alphanumeric J. http://dx.doi.org/10.17093/alphanumeric.353957.

Ben Jebli, M., Ben Youssef, S., 2015. The environmental Kuznets curve, economic growth, renewable and non-renewable energy, and trade in Tunisia. Renew. Sustain. Energy Rev. 47, 173–185. http://dx.doi.org/10.1016/j.rser.2015.02.049.

Bibi, F., Jamil, M., 2021. Testing environment Kuznets curve EKC hypothesis in different regions. Environ. Sci. Pollut. Res. 2811, 13581–13594.

Bilgili, F., Koçak, E., Bulut, Ü., 2016. The dynamic impact of renewable energy consumption on CO2 emissions: a revisited Environmental Kuznets Curve approach. Renew. Sustain. Energy Rev. 54, 838–845.

Boontome, P., Therdyothin, A., Chontanawat, J., 2017. Investigating the causal relationship between non-renewable and renewable energy consumption, CO2 emissions and economic growth in Thailand. Energy Procedia 138, 925–930.

Chen, Y., Wang, Z., Zhong, Z., 2019. CO2 emissions, economic growth, renewable and non-renewable energy production and foreign trade in China. Renew. Energy http://dx.doi.org/10.1016/j.renene.2018.07.047.

Destek, M.A., Aslan, A., 2017. Renewable and non-renewable energy consumption and economic growth in emerging economies: Evidence from bootstrap panel causality. Renew. Energy 111, 757–763. http://dx.doi.org/10.1016/j.renene.2017.05.008.

Dong, K., Sun, R., Li, H., Liao, H., 2018. Does natural gas consumption mitigate CO2 emissions: testing the environmental kuznets curve hypothesis for 14 Asia-Pacific countries. Renew. Sustain. Energy Rev. 94, 419–429.

Doytch, N., 2020. The impact of foreign direct investment on the ecological footprints of nations. Environ. Sustain. Indic. 8, 100085.

Faisal, F., Tursoy, T., Gunsel Resatoglu, N., Berk, N., 2018. Electricity consumption, economic growth, urbanisation and trade nexus: empirical evidence from Iceland. Econ. Res. Istraž. 31, 664–680. http://dx.doi.org/10.1080/1331677X.2018.1438907.

Farhani, S., Chaibi, A., Rault, C., 2014. CO2 emissions, output, energy consumption, and trade in Tunisia. Econ. Model. 38, 426–434. http://dx.doi.org/10.1016/j.econmod.2014.01.025.

Godil, D.I., Ahmad, P., Ashraf, M.S., Sarwat, S., Sharif, A., Shabib-ul-Hasan, S., Jermsittiparsert, K., 2021. The step towards environmental mitigation in Pakistan: do transportation services, urbanization, and financial development matter? Environ. Sci. Pollut. Res. http://dx.doi.org/10.1007/s11356-020-11839-0.

Gregory, A.W., Hansen, B.E., 1996. Residual-based tests for cointegration in models with regime shifts. Journal of Econometrics 70 (1), 99–126.

Grossman, G., Krueger, A., 1991. *Environmental Impacts of a North American Free Trade Agreement* (No. 3914). National Bureau of Economic Research, Inc..

Gygli, S., Haelg, F., Potrafke, N., Sturm, J.E., 2019. The KOF globalisation index–revisited. The Review of International Organizations 14 (3), 543–574.

Halicioglu, F., 2009. An econometric study of CO2 emissions, energy consumption, income and foreign trade in Turkey. Energy Policy 373, 1156–1164.

Hanif, I., 2018. Impact of economic growth, nonrenewable and renewable energy consumption, and urbanization on carbon emissions in Sub-Saharan Africa. Environ. Sci. Pollut. Res. 2515, 15057–15067.

Haseeb, A., Xia, E., Danish, Baloch, M.A., Abbas, K., 2018. Financial development, globalization, and CO2 emission in the presence of EKC: evidence from BRICS countries. Environ. Sci. Pollut. Res. http://dx.doi.org/10.1007/s11356-018-3034-7.

Hatemi-J, A., 2008. Tests for cointegration with two unknown regime shifts with an application to financial market integration. Empirical Economics 35 (3), 497–505.

Hossain, S., 2012. An econometric analysis for CO_2 emissions, energy consumption, Economic Growth, Foreign trade and urbanization of Japan. Low Carbon Econ. 03, 92–105. http://dx.doi.org/10.4236/lce.2012.323013.

Iorember, P.T., Jelilov, G., Usman, O., Işık, A., Celik, B., 2021. The influence of renewable energy use, human capital, and trade on environmental quality in South Africa: multiple structural breaks cointegration approach. Environ. Sci. Pollut. Res. 28 (11), 13162–13174.

Joshua Sunday Riti, Y.S., 2016. Renewable energy, energy efficiency, and eco-friendly environment (R-E5) in Nigeria. Energy. Sustain. Soc..

Kalayci, C., Hayaloglu, P., 2019. The impact of economic globalization on CO2 emissions: The case of NAFTA countries. Int. J. Energy Econ. Policy 9, 356–360.

Kasman, A., Duman, Y.S., 2015. CO2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: A panel data analysis. Econ. Model. 44, 97–103. http://dx.doi.org/10.1016/j.econmod.2014.10.022.

Khan, M.K., Khan, M.I., Rehan, M., 2020. The relationship between energy consumption, economic growth and carbon dioxide emissions in Pakistan. Financ. Innov. 61, 1–13.

Khan, Z., Murshed, M., Dong, K., Yang, S., 2021. The roles of export diversification and composite country risks in carbon emissions abatement: Evidence from the signatories of the Regional Comprehensive Economic Partnership agreement. Appl. Econ. http://dx.doi.org/10.1080/00036846.2021.1907289.

Khan, M.K., Teng, J.Z., Khan, M.I., Khan, M.O., 2019. Impact of globalization, economic factors and energy consumption on CO2 emissions in Pakistan. Sci. Total Environ. 688, 424–436. http://dx.doi.org/10.1016/j.scitotenv.2019.06.065.

Kirikkaleli, D., Adebayo, T.S., 2021. Do public–private partnerships in energy and renewable energy consumption matter for consumption-based carbon dioxide emissions in India? Environ. Sci. Pollut. Res. http://dx.doi.org/10.1007/s11356-021-12692-5.

Koc, S., Bulus, G.C., 2020. Testing validity of the EKC hypothesis in South Korea: role of renewable energy and trade openness. Environ. Sci. Pollut. Res. 2723, 29043–29054.

Koengkan, M., 2017. The nexus between energy consumption, economic growth, and urbanization in Latin American and Caribbean countries: An approach with PVAR model. Rev. Valore 2, 202–219. http://dx.doi.org/10.22408/reva22201761202-219.

Koengkan, M., Fuinhas, J.A., 2020a. Exploring the effect of the renewable energy transition on CO_2 emissions of Latin American and Caribbean countries. Int. J. Sustain. Energy 39, 515–538. http://dx.doi.org/10.1080/14786451.2020.1731511.

Koengkan, M., Fuinhas, J.A., 2020b. The interactions between renewable energy consumption and economic growth in the Mercosur countries. Int. J. Sustain. Energy 39, 594–614. http://dx.doi.org/10.1080/14786451.2020.1732978.

Koengkan, M., Fuinhas, J.A., Silva, N., 2021. Exploring the capacity of renewable energy consumption to reduce outdoor air pollution death rate in Latin America and the Caribbean region. Environ. Sci. Pollut. Res. 282, 1656–1674.

Koengkan, M., Poveda, Y.E., Fuinhas, J.A., 2020. Globalisation as a motor of renewable energy development in Latin America countries. GeoJournal 85, 1591–1602. http://dx.doi.org/10.1007/s10708-019-10042-0.

Lean, H.H., Smyth, R., 2010. CO2 emissions, electricity consumption and output in ASEAN. Appl. Energy 87, 1858–1864. http://dx.doi.org/10.1016/j.apenergy.2010.02.003.

Liu, M., Ren, X., Cheng, C., Wang, Z., 2020. The role of globalization in CO2 emissions: a semi-parametric panel data analysis for G7. Sci. Total Environ. 718, 137379.

Maki, D., 2012. Tests for cointegration allowing for an unknown number of breaks. Econ. Model. 29, 2011–2015. http://dx.doi.org/10.1016/j.econmod.2012.04.022.
Mehmood, U., 2021. Globalization-driven CO 2 emissions in Singapore: an application of ARDL approach. Environ. Sci. Pollut. Res. 28 (9), 11317–11322.
Mehrara, M., 2007. Energy consumption and economic growth: the case of oil exporting countries. Energy Policy 355, 2939–2945.
Murshed, M., 2020. An empirical analysis of the non-linear impacts of ICT-trade openness on renewable energy transition, energy efficiency, clean cooking fuel access and environmental sustainability in South Asia. Environ. Sci. Pollut. Res. 2729, 36254–36281. http://dx.doi.org/10.1007/s11356-020-09497-3.
Murshed, M., 2021a. Can regional trade integration facilitate renewable energy transition to ensure energy sustainability in South Asia?. Energy Reports 7 (C), 808–821. http://dx.doi.org/10.1016/j.egyr.2021.01.038.
Murshed, M., 2021b. Modeling primary energy and electricity demands in Bangladesh: An autoregressive distributed lag approach. Sustainable Production and Consumption 27, 698–712. http://dx.doi.org/10.1016/j.spc.2021.01.035.
Murshed, M., Ahmed, Z., Alam, M.S., Mahmood, H., Rehman, A., Dagar, V., 2021c. Reinvigorating the role of clean energy transition for achieving a low-carbon economy: evidence from Bangladesh. Environ. Sci. Pollut. Res. http://dx.doi.org/10.1007/s11356-021-15352-w.
Murshed, M., Ahmed, R., Kumpamool, C., Bassim, M., Elheddad, M., 2021b. The effects of regional trade integration and renewable energy transition on environmental quality: Evidence from South Asian neighbours. Business Strategy and the Environment http://dx.doi.org/10.1002/bse.2862.
Murshed, M., Alam, R., Ansarin, A., 2021a. The Environmental Kuznets Curve Hypothesis for Bangladesh: The importance of natural gas, liquefied petroleum gas and hydropower consumption. Environ. Sci. Pollut. Res 28 (14), 17208–17227. http://dx.doi.org/10.1007/s11356-020-11976-6.
Nathaniel, S.P., Iheonu, C.O., 2019. Carbon dioxide abatement in Africa: the role of renewable and non-renewable energy consumption. Sci. Total Environ. 679, 337–345.
Nathaniel, S.P., Nwulu, N., Bekun, F., 2021. Natural resource, globalization, urbanization, human capital, and environmental degradation in Latin American and Caribbean countries. Environ. Sci. Pollut. Res. 28, 6207–6221. http://dx.doi.org/10.1007/s11356-020-10850-9.
Nazir, M.I., Nazir, M.R., Hashmi, S.H., Ali, Z., 2018. Environmental Kuznets Curve hypothesis for Pakistan: Empirical evidence form ARDL bound testing and causality approach. Int. J. Green Energy http://dx.doi.org/10.1080/15435075.2018.1529590.
Nazlioglu, S., Gormus, N.A., Soytas, U., 2016. Oil prices and real estate investment trusts (REITs): Gradual-shift causality and volatility transmission analysis. Energy Econ. 60, 168–175. http://dx.doi.org/10.1016/j.eneco.2016.09.009.
Odhiambo, N.M., 2012. Economic growth and carbon emissions in South Africa: An empirical investigation. J. Appl. Bus. Res. http://dx.doi.org/10.19030/jabr.v28i1.6682.
Ozturk, I., Acaravci, A., 2013. The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. Energy Econ. 36, 262–267. http://dx.doi.org/10.1016/j.eneco.2012.08.025.
Pata, U.K., 2018. Renewable energy consumption, urbanization, financial development, income and CO2 emissions in Turkey: Testing EKC hypothesis with structural breaks. J. Clean. Prod. 187, 770–779. http://dx.doi.org/10.1016/j.jclepro.2018.03.236.
Pata, U.K., 2021. Renewable and non-renewable energy consumption, economic complexity, CO 2 emissions, and ecological footprint in the USA: testing the EKC hypothesis with a structural break. Environ. Sci. Pollut. Res. 281, 846–861.
Pata, U.K., Caglar, A.E., 2021. Investigating the EKC hypothesis with renewable energy consumption, human capital, globalization and trade openness for China: Evidence from augmented ARDL approach with a structural break. Energy 216, 119220.
Phillips, P.C.B., Hansen, B.E., 1990. Statistical inference in instrumental variables regression with i(1) processes. Rev. Econ. Stud. 57, 99–125. http://dx.doi.org/10.2307/2297545.
Qin, L., Raheem, S., Murshed, M., Miao, X., Khan, Z., Kirikkaleli, D., 2021. Does financial inclusion limit carbon dioxide emissions? Analyzing the role of globalization and renewable electricity output. Sustain. Dev. http://dx.doi.org/10.1002/sd.2208.
Rafindadi, A.A., 2016. Does the need for economic growth influence energy consumption and CO2 emissions in Nigeria? Evidence from the innovation accounting test. Renew. Sustain. Energy Rev. 62, 1209–1225. http://dx.doi.org/10.1016/j.rser.2016.05.028.
Rahman, M.M., Nepal, R., Alam, K., 2021. Impacts of human capital, exports, economic growth and energy consumption on CO2 emissions of a cross-sectionally dependent panel: Evidence from the newly industrialized countries NICs. Environ. Sci. Policy 121, 24–36.
Rana, R., Sharma, M., 2019. Dynamic causality testing for EKC hypothesis, pollution haven hypothesis and international trade in India. J. Int. Trade Econ. Dev. 283, 348–364.
Saboori, B., Sulaiman, J., Mohd, S., 2012. Economic growth and CO2 emissions in Malaysia: A cointegration analysis of the Environmental Kuznets Curve. Energy Policy 51, 184–191. http://dx.doi.org/10.1016/j.enpol.2012.08.065.
Saidi, K., Ben Mbarek, M., 2016. Nuclear energy, renewable energy, CO 2 emissions, and economic growth for nine developed countries: Evidence from panel Granger causality tests. Prog. Nucl. Energy 88, 364–374. http://dx.doi.org/10.1016/j.pnucene.2016.01.018.
Saidi, K., Hammami, S., 2016. Economic growth, energy consumption and carbone dioxide emissions: recent evidence from panel data analysis for 58 countries. Qual. Quant. 50, 361–383. http://dx.doi.org/10.1007/s11135-014-0153-1.
Salahuddin, M., Gow, J., Ali, M.I., Hossain, M.R., Al-Azami, K.S., Akbar, D., Gedikli, A., 2019. Urbanization-globalization-CO2 emissions nexus revisited: empirical evidence from South Africa. Heliyon 5 (6), e01974.
Sánchez-Chóliz, J., Duarte, R., 2004. CO2 emissions embodied in international trade: evidence for Spain. Energy Policy 3218, 1999–2005.
Sapkota, P., Bastola, U., 2017. Foreign direct investment, income, and environmental pollution in developing countries: Panel data analysis of Latin America. Energy Econ. 64, 206–212.
Shahbaz, M., Hye, Q.M.A., Tiwari, A.K., Leitão, N.C., 2013a. Economic growth, energy consumption, financial development, international trade and CO2 emissions in Indonesia. Renew. Sustain. Energy Rev. 25, 109–121.
Shahbaz, M., Khan, S., Ali, A., Bhattacharya, M., 2017. The impact of globalization on CO2 emissions in China. Singap. Econ. Rev. 6204, 929–957.
Shahbaz, M., Solarin, S.A., Mahmood, H., Arouri, M., 2013b. Does financial development reduce CO2 emissions in Malaysian economy? A time series analysis. Econ. Model. 35, 145–152.
Sheinbaum, C., Ruíz, B.J., Ozawa, L., 2011. Energy consumption and related CO2 emissions in five Latin American countries: Changes from 1990 to 2006 and perspectives. Energy 366, 3629–3638.
Sinha, A., Shahbaz, M., 2018. Estimation of Environmental Kuznets Curve for CO2 emission: Role of renewable energy generation in India. Renew. Energy http://dx.doi.org/10.1016/j.renene.2017.12.058.
Stock, J.H., Watson, M.W., 1993. A Simple Estimator of Cointegrating vectors in higher order integrated systems. Econometrica 61 (783), http://dx.doi.org/10.2307/2951763.
Tenaw, D., Beyene, A.D., 2021. Environmental sustainability and economic development in sub-Saharan Africa: A modified EKC hypothesis. Renew. Sustain. Energy Rev. 143, 110897.
Toda, H.Y., Yamamoto, Taku, 1995. Statistical inference in vector autoregressions with possibly integrated processes. J. Econom. 66, 225–250.
Wang, S.S., Zhou, D.Q., Zhou, P., Wang, Q.W., 2011. CO2 emissions, energy consumption and economic growth in China: A panel data analysis. Energy Policy 39, 4870–4875. http://dx.doi.org/10.1016/j.enpol.2011.06.032.
Westerlund, J., Edgerton, D.L., 2007. New improved tests for cointegration with structural breaks. Journal of time series Analysis 28 (2), 188–224.
World Bank, 2020. World Development Indicators. World Bank.
Xia, C., Wang, Z., 2020. The effect of fossil fuel and hydropower on carbon dioxide emissions: EKC validation with structural breaks. J. Environ. Eng. Landsc. Manage. 28 (1), 36–47.
Yang, X., Li, N., Mu, H., Pang, J., Zhao, H., Ahmad, M., 2021. Study on the long-term impact of economic globalization and population aging on CO2 emissions in OECD countries. Sci. Total Environ. 787, 147625.
Yilanci, V., Pata, U.K., 2020. Investigating the EKC hypothesis for China: the role of economic complexity on ecological footprint. Environ. Sci. Pollut. Res. 27, 32683–32694.
Zafar, M.W., Mirza, F.M., Zaidi, S.A.H., Hou, F., 2019b. The nexus of renewable and nonrenewable energy consumption, Trade Openness, and CO2 emissions in the Framework of EKC: Evidence from Emerging Economies. Environ. Sci. Pollut. Res. 2615, 15162–15173.
Zafar, M.W., Saud, S., Hou, F., 2019a. The impact of globalization and financial development on environmental quality: Evidence from selected countries in the organization for economic co-operation and development (OECD). Environ. Sci. Pollut. Res. http://dx.doi.org/10.1007/s11356-019-04761-7.
Zhang, L., Li, Z., Kirikkaleli, D., Adebayo, T.S., Adeshola, I., Akinsola, G.D., 2021. Modeling CO2 emissions in Malaysia: an application of maki cointegration and wavelet coherence tests. Environ. Sci. Pollut. Res. 28 (20), 26030–26044.
Zivot, E., Andrews, D.W.K., 1992. Further evidence on the Great Crash, the oil-price shock, and the Unit-Root Hypothesis. J. Bus. Econom. Statist. 10, 251. http://dx.doi.org/10.2307/1391541.