International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied


International Journal of Sciences: Basic and Applied Research
ISSN 2307-4531
(Print & Online)
Published by:

Investigating the Validity of the Agricultural-Induced Environmental Kuznets Curve (EKC) Hypothesis for Pakistan: Evidence from Autoregressive Distributed Lag (ARDL) Approach with a Structural Break

Rabia Mazhar[a], Houjian Li[b]*, Gideon Ntim-Amo[c], Abdul Saboor[d], Ayesha Ali[e]

[a,c]*College of management, Sichuan agricultural university, Chengdu 611130, China*
[b]*College of economics, Sichuan agricultural university, Chengdu 611130, China*
[d]*Dean Faculty of Social Sciences, PMAS Arid Agriculture University, Rawalpindi, Pakistan*
[e]*School of economics and finance, Queen Mary University of London, Mile End Rd, Bethnal Green, London E1 4NS*
[a,c]*Email: rabiamazhar20@outlook.com*, [b]*Email:14159@sicau.edu.cn*, [c]*Email: drabdul.saboor@uaar.edu.pk*,
[e]*Email: ayesha.ali@hss21.qmul.ac.uk*

Abstract

The objective of this study is to check the feasibility of the agriculture-induced EKC hypothesis for Pakistan from 1971 to 2014 using findings from an autoregressive distributed lag (ARDL) technique with a structural break that includes real income and energy consumption in the model. The agriculture-induced EKC model was studied using the autoregressive distributed lag (ARDL) technique with a structural break, which has never been explored before in Pakistan. The direction of relationship between the research factors was explained with Toda-Yamamoto Granger Causality test. GDP and GDPSQ all have significant positive effects on CO_2 emissions, while GDPSQ reduces CO_2 emissions, according to the ARDL findings. The results of the Toda-Yamamoto causality test reveal a long-run unidirectional causation exists between GDP, GDPSQ and long-run CO_2 emissions. A long-run unidirectional causal relationship between AGRIC, GDPSQ and GDP and bidirectional long-run causal link between energy consumption and GDP was established. The presence of the agriculture-induced EKC hypothesis in Pakistan in the short and long run was substantiated by the bidirectional and unidirectional causal links between the two variables and GDP.

---

* Corresponding author.

As a result, special strategies to increase institutional quality in Pakistan are proposed to reduce unsustainable agricultural practices in preparation for a worldview transition from primitive technology to modern sustainable agrarian technologies. This work is unique in the EKC literature in Pakistan since no other study has been done on agriculture-induced EKC in Pakistan, and other EKC studies have failed to account for structural breaks, as this study has done. This study also contains a causality analysis to look into the direction of the link, which is something that the few EKC studies in Pakistan haven't investigated into.

Keywords: GDP; GDPSQ; Carbon dioxide emissions; AGRIC; Energy consumption; EKC hypothesis; Structural break; ARDL model; Causality.

1. Introduction

The widespread use of fossil fuels, such as oil, gas, and charcoal, has shaped industrial history. Because of fossil fuels, humanity has attained unprecedented levels of economic progress and wealth, however these achievements have cost a lot to the surroundings. Other variables that follow economic advancement, including rapid population growth, developed infrastructure, early exposure, increasing demands among residents, and worldwide trade, have exacerbated environmental concerns [1,2]. The acknowledgment of these advancements' substantial environmental costs put the concept of sustainability onto the table, and until the World Development Report of 1992, the concept of sustainability has been on the agenda [3], and academics, policy professionals, and international institutions are now debating and researching the link of economic expansion and environmental challenges [4].

The Kuznets' curve model, proposed by Simon Kuznets during 1950s, depicts an inverse U-shaped link between income per capita and wage inequality [5]. According to Kuznets, income inequality rises in the early stages of a nation's economic development, reaches a peak, and then tends to be less severe after a threshold point of view of economic development. Because of the growing importance of environmental concerns, the notable Kuznets' curve was updated in the year 1990 to show the link between income level and environmental quality.

Studies like [6,7] independently stated that there exists an estimated inverse U-shaped link between economic growth and environmental quality, based on Kuznets' original hypothesis. This correlation explains how environmental destruction rises in the early stages of a country’s economic growth (owing to inadequate manufacturing techniques); nevertheless, as income level increase, a change towards environmentally friendly manufacturing processes occurs and thus environmental damage falls. Panayotou termed this inverse U-shaped link between economic growth and environmental destruction the environmental Kuznets' curve (EKC) (1993). The proposal sparked a lot of discussion among academics. Following the key studies of [6,9], a research formed, with support for the relevance of the EKC theory [10]. Using different empirical methodologies, a great number of publications studied and verified EKC hypothesis in various nations during the last two decades. Its validity has been accepted by numerous literatures.

Agriculture is one of every country's most vital economic sector. Even though its importance as a primary determinant of economic progress has been recognized for millennia, the online world and internationalization have greatly increased it. Agriculture's research and development (R&D) has a very good return [11], and agriculture continues to be a major contributor to gains in national economies' total productivity [12,13]. As a result, agricultural expertise helps a nation to boost its economic development pace by improving its efficiency. It is well proven that agricultural expansion has a bigger impact on poverty reduction in emerging countries than growth in other industries [14].

The agricultural sector has these features, making it a valuable strategy for developing economies [15]. Changes in the global food market, on the other hand, have provided new difficulties and opportunity for developing economies over the last two decades, along with a major growth in agricultural investment and economic growth [16], rapidly rising R&D efforts, elevated foreign investment (FDI), and improved food regulations [17]. Growing amount of traded agricultural products [15,18] as well as increased export percentages of emerging economies in quality product categories emerging economies to enhance agricultural output. Further agricultural output, on the other hand, leads to higher energy consumption, particularly of fossil fuels [19], [20] and hence leads to increased $\mathrm{CO_2}$ emission [21], environmental damage, deforestation, and inadequate water quality.

The connection among agriculture and destruction of the environment has shifted significantly over the recent two years as a result of variables such as increasing energy prices, technical improvements, and impact of environmental policies that support the correlation between the agriculture and energy industries. Energy expenses increased and were more unpredictable from 2001 to 2012 [22]. During this time, farmers saw an increased pattern in the pricing of inputs related to energy. On the one side, the price increase impacted the agricultural sector's profitability and produced changes in the sector's energy usage patterns [23]. Higher energy prices, from the other side, pushed other businesses to look for other sources of energy, and the energy industry's need for agricultural products as renewable fuel sources, such as feedstock, increased dramatically. Biofuel markets have advanced due to other considerations like as domestic energy security, countryside economic expansion, and environmental consciousness. As a result of these processes, each connection among agriculture and energy, wherein agriculture takes energy as a source and has become a net energy consumer, has transformed into a 2 different, reciprocal interaction. Because the agricultural sector is now both a supplier and a consumer of energy inputs, the agriculture-energy link is increasingly complex and crucial to understand [24]. The link among agricultural production and energy-environmental challenges also evolved as a result of technological advancements. Increased global sensitivity to environmental deterioration, as well as higher fossil fuel prices, have pushed the implementation of technologies and manufacturing processes that can save natural resources and energy. Improved energy efficiency boosts efficiency by cutting costs while also lowering greenhouse gas (GHG) emissions and having a significant effect on the environment [25].

Agriculture is an important option for upgrading the standard EKC model because of changes in the agriculture-environment relationship, as well as the agricultural energy usage trends. To a knowledge of the researcher’s understanding there is just one research in the relevant publications [26] that uses the EKC framework to investigate the link between agriculture industry developments and environmental deterioration. Considering the significance of agriculture and its evolving connection to energy-environmental concerns, expanding the EKC theory to include agriculture in Pakistan (what we call the agriculture-induced EKC hypothesis) add to the current academic evidence.

The recent study investigates hypothesis as well as the and the robustness or responsivity of calculated EKC models [27]. The use of the proper econometric approach determines the accuracy of the conclusions. Previous studies that evaluated the EKC theory using cross-sectional or panel survey produced mixed results [28]. These conflicting results, according to [29], are most likely due to aggregation bias, that indicates that a substantial (insignificant) economic output with one nation could be greater than compensated by effective (non - significant) economic output with different nations. Moreover, [30] stated that the EKC, as derived from panel data, does not adequately reflect complex process to validate the notion that growth in economy is unrelated to external pressure in particular nations. To tackle this difficulty, many scholars prefer to look at specific countries using time series data [31–36]. This paper in hand employs the time series data to address the key subject of the development of the income-environment link in a single nation while avoiding the concerns of cross-sectional dependence [37] and heterogeneity [38]. We use econometric methodologies to fully adjust the data's integration and co-integration features [39]. In typical econometric methodologies, structural breakdowns in the series generate inaccuracies in the integration and co-integration properties of the series [40]. In this regard, the unit root test of [41] and the co-integration test of [42] took into consideration any hypothetical structural break. Instead of using the traditional Granger causality test, [43] causality test is used. Toda-Yamamoto's causality test has the advantage of being adaptable to any model's integration and co-integration properties [44].

Pakistan is used as a research area in this study to analyze the agriculture-induced EKC theory. The environmental performance index (EPI), developed by the Yale Center for Environmental Law and Policy (YCELP) and University's Department in partnership with the World Industry Conference, currently ranks Pakistan 148th out of 178 countries in context of ecological performance, indicating severe problems with the nation's environmental policies (2014). Pakistan's economy is based on agriculture, with the exports accounting for 25.1 percent of GDP in 2014 and 45 percent of the labor force [45]. As a result, enhanced agricultural production in Pakistan could increase growth in the economy, leading to increased energy consumption and, as a result, increased $\mathrm{CO_2}$ emissions. Because Pakistan is one of the world's fastest developing economies, energy demand is predicted to triple by 2050 [46]. According to Kyoto agreement in order to assist economic growth, Pakistan's government is working on steps to reduce pollution levels and ensure efficiency in the country [47]. As a result of such conditions, Pakistan presents an interesting study for examining the causal link between energy consumption, economic expansion, energy consumption, and agriculture as an assessment of the agriculture-induced EKC hypothesis, with utmost aim to gain efficient environmental policy. Other emerging nations may benefit from the result of this research in implementing comprehensive environmental policies.

This study employ country-specific time series data to examine the agricultural sector's impact on the environment, which addresses econometric issues such as aggregation biases [48], heterogeneity [39], and cross-sectional dependency [37]. The autoregressive distributed lag (ARDL) bounds test was used to approximate the association between the factors because it is the most robust technique for examining the EKC model in a time series analysis [49], and it considers different lag lengths of variables, making it more flexible than other methods [50]. The Granger Causality test was used to determine the direction of the link of the study factors.

This study is useful since the authors dealt with the issue of structural breaks, whereas many other studies in

Pakistan have ignored this critical issue, which has a positive response on the consistency and validity of the results produced. The second key contribution comes from a study by [51], which claims that the absence of a dominating contributor to the economy, like the agriculture sector, can alter an economy's EKC outcome. When the industrial portion of GDP was combined with economic growth, their study verified the EKC hypothesis for Turkey but failed to validate its presence. As a result, unlike many other EKC studies in Africa and Pakistan this one evaluated the hypothesis by taking into account the agricultural share of GDP. To the knowledge of the researchers, no empirical literature on EKC that assessed the agricultural sector's productivity in Pakistan.

As a possible result, this study in hand covers all the bases by examining the relationship between agricultural productivity and the EKC hypothesis in Pakistan, using CO_2 emissions as a pollution indicator and combining the agriculture share of GDP per capita, energy consumption, GDP per capita, and the square term of GDP per capita in a single equation to validate the presence of EKC. Other econometric techniques are used to stress the robustness of test results from a study. Finally, the study looks for causality trying to examine the direction of the link of factors in the EKC model. This contributes to the fact that many studies on EKC in Pakistan neglect to investigate the direction after establishing the association between the variables.

The following is how the rest of this article will be organized: The literature review, materials, and methods used for analysis are covered in the second section; the empirical findings and discussion are covered in the fourth section; and the conclusion and recommended policies are presented in the last section.

2. Theoretical Framework

Empirical studies that attempt to verify the significance of the EKC hypothesis are influenced by the dependent variable, independent variables, nation and duration of the study, economic method, and statistical techniques. Options about the effect attributed to these factors in various models, are the key causes for contradictory findings on the verification of the EKC hypothesis. As a result, to obtain robust and trustworthy conclusions, it is necessary to be specific about the review conducted regarding the function of these variables in EKC models.

The EKC is a model that depicts the link between income growth and pollution levels in the environment. Environmental deterioration is the model's dependent variable, and it can be proxied by different factors, considering different biological diversity [52], contaminants [53], and pollutants, which is the most widely employed proxy variable (due to its availability). Pollutants are divided into two categories: those that have local impacts and those that have global consequences. CO_2 is a worldwide emission that is used in many EKC models [54–63]. This decision was made for a variety of reasons. For starters, carbon emissions are an important component to consider when discussing and recommending policies. CO_2 accounts for 76.7 percent of greenhouse gas (GHG) emissions, according to the IPCC (2006), which is an important number for decision-makers, economic planning, and environmental preservation.

Emission of carbon dioxide is linked to major sustainability issues such global warming, greenhouse gas emissions, and climate change. Given that global climate change mitigation is a top priority for contemporary international development efforts, it's critical to identify variables that influence CO_2 emissions [64]. Carbon dioxide's costs extend beyond the time and location where it is emitted since it is a global emission. As a result, though "free rider" difficulties arise, wherein nations can produce CO_2 despite bearing the entire cost. Due to the worldwide nature of CO_2 effects, examining the link between economic development and pollution in localized settings is frequently challenging, leading to a lack of clarity in economics and policy decisions. These challenges add to the attraction of the study. For the reasons described above, we used per capita carbon dioxide emissions as the dependent variable in our agriculture-induced EKC model.

The EKC is a reduced form connection [6] that tries to assess the overall impact of income increase on environmental quality. The influence of all other parameters on the link among economic growth and environmental deterioration shown by the primary reduced model can be captured by adding nonstructural variables to the EKC model [65]. It may be possible to identify any trend that is obscured by the assessment of the reduced form model using nonstructural variables. In addition, including non-structural factors can enhance econometric characteristics and the residual quality of estimates [27]. As a result, if a variable is stated to have a positive effect on environmental quality, integrating it in the classic EKC model will yield superior findings and allow us to examine the connection better under study. Numerous factors, including labor and capital, have been included in EKC model in different studies to attain this purpose [66,67], similarly trade [68–72] and energy consumption [73–76]. Following prior research that demonstrated the link of income growth and pollution by including a specific sector of the economy into the EKC model [77], this study in hand adds the agricultural sector representing as independent variable to the traditional EKC model. This is the paper's key contribution, and we believe it will help us better to grasp the link indicated by the EKC hypothesis. We also include energy use in the model because ignoring its importance would lead to estimation bias in the results [78].

The EKC theory has stimulated the interest of investigators who want to find out if it's true. One explanation for this attention is what [27] refers to as the model's Batomic structure, which is adaptable to many modeling methodologies. Researchers have employed a variety of model specifications to analyze the EKC hypothesis, following the publication of [79]. The EKC hypothesis, as stated previously, depicts an inverse U-shaped link among economic growth and environmental quality as explained in the related studies [80,61,68,81–86].

3. Literature Review

The Kuznets model is based on [5] seminal research demonstrating inverse U-shaped link among income per capita and wage disparity, which he published in 1955. Between these two components, there is a two-way interaction. Income inequality grows when per capita income rises at initially (low income), till inequality begins to decline when per capita income rises (high income) at some point (middle class), and eventually the economy converges to income equality [5]. Following the Kuznets curve theory, Reference [6] pioneered research into the link between income growth and environmental quality. The investigation discovered an inverted U-shaped association, validating the reality of the Kuznets curve hypothesis. Later research by [8,87–89] demonstrated that emissions rise in the early phases of development, but air quality improves beyond the middle stage, and pollution declines in the later stages as the country develops. As a result, the inverse U-shaped curve is depicted to support the idea. These seminal contributions opened the path for the development of the environmental Kuznets curve (EKC), which has been embraced by policymakers and environmental scientists.

Over the last two decades, various empirical studies testing the EKC hypothesis have been conducted to investigate the topic in depth utilizing various econometric instruments for individual or cross-country research.

The importance of fossil fuel in achieving economic growth has been proven in recent studies [90–93]. Most developing nations fail to exhibit a clear stage of removing CO_2 emissions from economic growth [94], and the economic effect of GDP per capita is the major force driving the increase in CO_2 emissions [95]. The evidence of rising carbon emissions from economic growth is backed up by the lack of literature [90,91,96–98]. As Pakistan's economy expands as a result of growth in the service, agriculture, and export industries, CO_2 emissions will inevitably rise. Reference [99] used this relationship to show that the link of rising income per capita and environmental degradation is inverse U-shaped, just as [5] predicted in his research on economic growth and income inequality. This study in hand is motivated to analyze the verification of the environmental Kuznets curve (EKC) theory in the face of agriculturally-induced economic expansion in a developing country like Pakistan.

Many scholars, particularly environmental economist, have turned to the EKC as a resource for environmental policy aimed at a low-carbon economy. Many researchers used various variables, and different econometric approaches that produced diversified results in different countries and areas, according to previous empirical literature [62]. Several study results confirm the existence of the EKC in nations using methodological approaches with the addition of many independent variables like energy consumption [28,100–104], renewable energy consumption [101,105,106] foreign direct investment [35,107], trade openness [62,100,108,109], labour force [101] , urbanization [109], globalization index [110], financial development [111], environmental regulations [104], household consumption expenditure [102], electricity production [103], and electricity consumption [106]. The other school of thought failed to confirm the presence of EKC in the countries studied using a similar set of variables [63,112–114] such as indicators also including coal consumption [115], total suspended particulate [116], labor force [80]. This discrepancy in results suggests that the EKC hypothesis varies per country, and that the presence of other major variables that influence economic growth can influence the conclusions as well as the methodology used [51,74,117–119]. The majority of these research found EKC to be present with CO_2 per capita as a pollution indicator in both developing and developed countries.

Researchers have also added economic sectors to the EKC model to verify the link between economic growth and environmental quality. The manufacturing sector [120–122], the tourist industry [77,123–125] , the financial sector [68,111,126–131]. Despite its economic importance and environmental consequences, agriculture has received little attention in this area, [22] for Pakistan, [132] for Azerbaijan, and [22] for China being the only notable studies to the authors' knowledge. With no previous research on Pakistan, specifically Punjab, this study is the first to include the agricultural sector as an independent variable in the EKC framework, allowing for a more in-depth examining the empirical link of economic growth and environmental degradation in Pakistan.

Recent literatures have established the effect of agricultural operations on greenhouse gas emissions. Reference [133,134] discovered a link between fertilizer application and N2O emissions. CO_2 emissions rise with agricultural activities [105,108,135] such as crop residue burning [136] and manure application increase [137]. There are few studies on Pakistan that include the agricultural sector's impact on CO_2 emissions, and no such study has yet been conducted in the context of the EKC hypothesis. Employing ARDL, Johansen Cointegration test, and Granger causality test, Reference [138] discovered a positive influence of cereal output, stock of livestock, agricultural technologies, biomass burned agricultural residues, and other crop productions on CO_2 emissions. This study looks into the topic of probable bias that might occur from focusing on certain agricultural activities rather than the entire agriculture sector's impact on emissions. As a result, this study varies from previous studies that focused on specific agricultural activities since it considers the entire agricultural sector's productivity.

Despite research on agriculture's impact on emissions, scholars and economists have paid very little attention to literature on agriculture's role in CO_2 emissions under the EKC frame, with only a few studies completed in recent years. Given the importance of agriculture in a country's economy and the effect of agricultural production on emissions, more research is needed, particularly in developing countries like Pakistan. Reference [26] examined the link among energy consumption, agriculture, GDP, GDPSQ, and CO_2 emissions in Turkey from 1968 to 2016 using the ARDL technique. The data demonstrate that GDP and CO_2 emissions have a strong positive long-run and short-run association, whereas agriculture has an adverse impact on CO_2 emissions for both periods. Recent literature have validated the favorable effect of agriculture on CO_2 emissions using factors like renewable energy [139], non-renewable energy consumption [140], and energy use (see first panel of Table I) [22,141]. Some studies have found negative effects of agriculture on CO_2 emissions, such as [142], who used data from 1970 to 2013 to analyze the link among CO_2 emissions per capita, renewable energy consumption, and agricultural value-added in Thailand, Indonesia, the Philippines, and Malaysia.

In the literature, only few researchers analyzed the relevance of the EKC hypothesis in regard to Pakistan’s total economy or its sub-sectors. The importance of agriculture to economic growth and development, the increasing link between agriculture and the environment, and agricultural energy use patterns have all made examining agriculture under the EKC hypothesis a top priority. However, to the best of the researchers' knowledge, no study has been conducted within the framework of the EKC that examined the impact of Pakistan’s agricultural industry on environmental pollution. This research paper in hand tries to fill this gap by incorporating the agricultural sector into the EKC framework for Pakistan’s scenario, based on recent research findings by [22, 50, 132].

Table I: Comprehensive review of the empirical literature.

Author /Year	Country/Region {Period of Study}	Methods	Variables	Results	EKC
Panel 1: Research conducted on the relationship among agriculture and CO_2 emissions					
[143]	China 1961–2012	ADF, PP, VECM, Johansen cointegration test, Granger causality test.	CO_2 emissions, biomass burned crop residues, agriculture value-added, enteric emissions of methane, emissions of N_2O from manure	CO_2 emissions will rise as rice, biomass-burned crop residues, and cereal output expand, but CO_2 emissions will drop as farm machinery expands. There is a bidirectional causal	

			application, emissions of CO_2 eq of N2O from synthetic fertilizers, stock of livestock, agricultural machinery, area of rice harvested, cereal production.	relationship between CO_2 emissions, biomass burned crop residues, and cereal output.	
[144]	China 1990-2016	ARDL, CCR, and Fully modified ordinary least square (FMOLS)	CO_2, Crop production, agricultural power consumption, livestock production and forest area.	Crop and livestock production increase CO_2 emissions whereas forest area and agricultural power consumption reduces emissions.	
[105], [145], [146]	Morocco 1980–2013	ARDL, Granger causality test	CO_2 emissions, GDP, agricultural value-added, arable land use, renewable energy consumption.	Renewable energy consumption will rise as GDP, agricultural value-added, and land use increase. Furthermore, agricultural value-added and renewable energy usage have a bidirectional causal relationship. Furthermore, there is a one-way relationship between agricultural value-added and renewable energy consumption.	
[105], [145], [146]	Tunisia 1980–2011	Johansen cointegration test, VECM, Granger causality test	CO_2 emissions, GDP, renewable and non-renewable energy consumption, trade openness, agricultural value-added	EKC isn't recommended. CO_2 emissions are favorably influenced by energy consumption, trade, agriculture value-added, and trade. In addition, all variables show long-run bi-directional causality.	YES
[147]	Brazil 1980–2011	ARDL, Granger causality test	CO_2 dioxide emissions, per capita combustible renewables and waste	Renewable energy, waste reduction, and agricultural value-added all boost GDP while lowering CO_2	YES

			consumption, agricultural value-added, GDP	emissions. From agriculture to CO_2 emissions and GDP, there is a chain of causality.	
[105], [145], [146]	Algeria, Egypt, Morocco, Sudan, Tunisia 1980–2011	LLC, IPS, Fisher-ADF, Fisher-PP, Pedroni cointegration test, VECM Granger causality test	CO_2 emissions, per capita GDP, agricultural value-added, renewable energy consumption	In the long run, agriculture reduces $CO_{2.}$ Renewable energy, on the other hand, increases emissions in the long run. Agriculture is a result of renewable energy, according to Granger. CO_2 and agriculture have a bidirectional causal relationship.	YES
[148]	Pakistan 1981-2015	VECM, FMOLS, and CCR, Toda-Yamamoto causality tes	Greenhouse gas emission, agriculture value-added, electricity production from coal sources, electricity production from hydroelectric sources, renewable energy supply, forest area, vegetable area	Renewables, agricultural value-added, vegetables, and forests all help to minimize GHG emissions. Between GHG, forest area, and agriculture value-added, there is Granger causation.	
[149]	Thailand, Malaysia, Philippines and Indonesia	Panel Cointegration, FMOLS, DOLS, OLS and Granger Causality	CO_2, GDP, agriculture, non-renewable and renewable energy.	Non-renewable energy consumption has increases CO_2 but renewable energy and agriculture affect CO_2 negatively.	NO
[150]	China 2001–2015	IPS, Fisher-ADF, Fisher-PP, Shapiro-Wilk test, Shapiro-Francia test, quantile-quantile regression	CO_2 emissions in the agriculture industry, level of industrialization, level of urbanization, energy efficiency, financial capacity, per capita GDP, population	In the upper 90th quantile and 75th–90th quantile provinces, economic expansion has a stronger impact on CO_2 emissions. Furthermore, urbanization has the greatest influence in provinces in the higher 90th quantile.	

[139]	G20 countries 1990-2014	Johansen cointegration test, VECM granger causality test	CO_2, GDP, renewable energy consumption and agriculture value added.	Agriculture affects CO_2 positively while renewable energy consumption reduces CO_2 emissions.	YES
[140], [149]	Indonesia, Malaysia, the Philippines, and Thailand 1970-2013	LLC, Breitung, IPS, Fisher-ADF, Fisher-PP, Pedroni and, Kao co-integration tests, OLS, FMOLS, DOLS, VECM Granger causality test	CO_2 emissions, renewable and non-renewable energy consumption, GDP, agriculture	The existence of EKC is unconfirmed. Increasing renewable energy consumption and agriculture lowers CO_2 emissions, but increasing non-renewable energy consumption raises CO_2 emissions.	
[151]	Portugal, France and Spain 1992-2014	ARDL	CO_2, agriculture value-added	In the long run, the EKC theory exists for Spain and France, and in the short run, it exists for all of the countries studied.	YES
[152]	Iran 1967–2015	KPSS, Johansen cointegration test, VECM Granger causality test	Agricultural energy consumption, agricultural real value added, agricultural real export value	Agriculture grows faster when energy usage rises. Granger's energy use also promotes agricultural expansion.	
[153]	China 1996-2015	ARDL, Granger Causality	Agricultural CO_2 emission and energy use	CO_2 emissions are reduced by agricultural energy usage.	YES
[154]	Latin America and the Caribbean countries 1990-2015	Tapio's (2005) decoupling elasticities	CO_2 from cultivated organic soils, non- CO_2 emissions, CH4 emissions, N2O emissions, CO_2 emissions associated with liming, CH4 emissions, CH4 and N2O emissions from manure management systems	Five countries use land-use carbon sequestration to offset agricultural emissions. Furthermore, top decoupling countries are not the same as countries with high factor productivity.	
[155]	Sichuan province-C- hina 1997–2008	OLS, LMDI			
[153]	China 1996-2015	ARDL, VECM Granger causality test,	Per capita CO_2 emissions, per	CO_2 emissions are highly connected with agricultural economic growth.	

		impulse response function, variance decomposition	capita net income of peasants	
[151]	France, Portugal and Spain 1992–2014	ARDL, ECM	Agricultural carbon emissions, agricultural energy consumption, agricultural economic growth	EKC has been verified for agricultural carbon emissions. Furthermore, the findings suggest that energy use drives both economic growth and carbon emissions in Granger.
[156]	Pakistan 1990–2014	ARDL, FMOLS, DOLS, VECM Granger causality test, variance decomposition	CO_2 emissions, agriculture added value, net value-added index per capita	Furthermore, the findings show that economic growth and carbon emissions have a bidirectional relationship.
			CO_2 emissions, renewable energy consumption, agricultural production, covered forest area	In the short term, EKC was affirmed for all countries, but only in the long term for France and Spain.

4. Data and econometric methodology

4.1. Data sources

This study aims to analyze Pakistan-specific data from 1971 to 2014. CO_2 emissions (metric tons per capita) were obtained from the World Bank's World Development Indicators (WDI) dataset as well as the remaining variables: GDP per capita (constant 2010 US$ per capita), energy consumption (kg of oil equivalent per capita), and Agriculture, forestry, and fishery, value added (constant 2010 US$). Because the data for energy consumption (kg of oil equivalent per capita) for Pakistan in the WDI database only goes up to 2014, the period 1971-2014 was chosen. As demonstrated by the graphs of all the series in Figure 3, the data was converted to natural logarithm form and included in the model. Various variations in the series can be seen in Figure 3, suggests the existence of structural breaks, which this study appropriately accounts for.

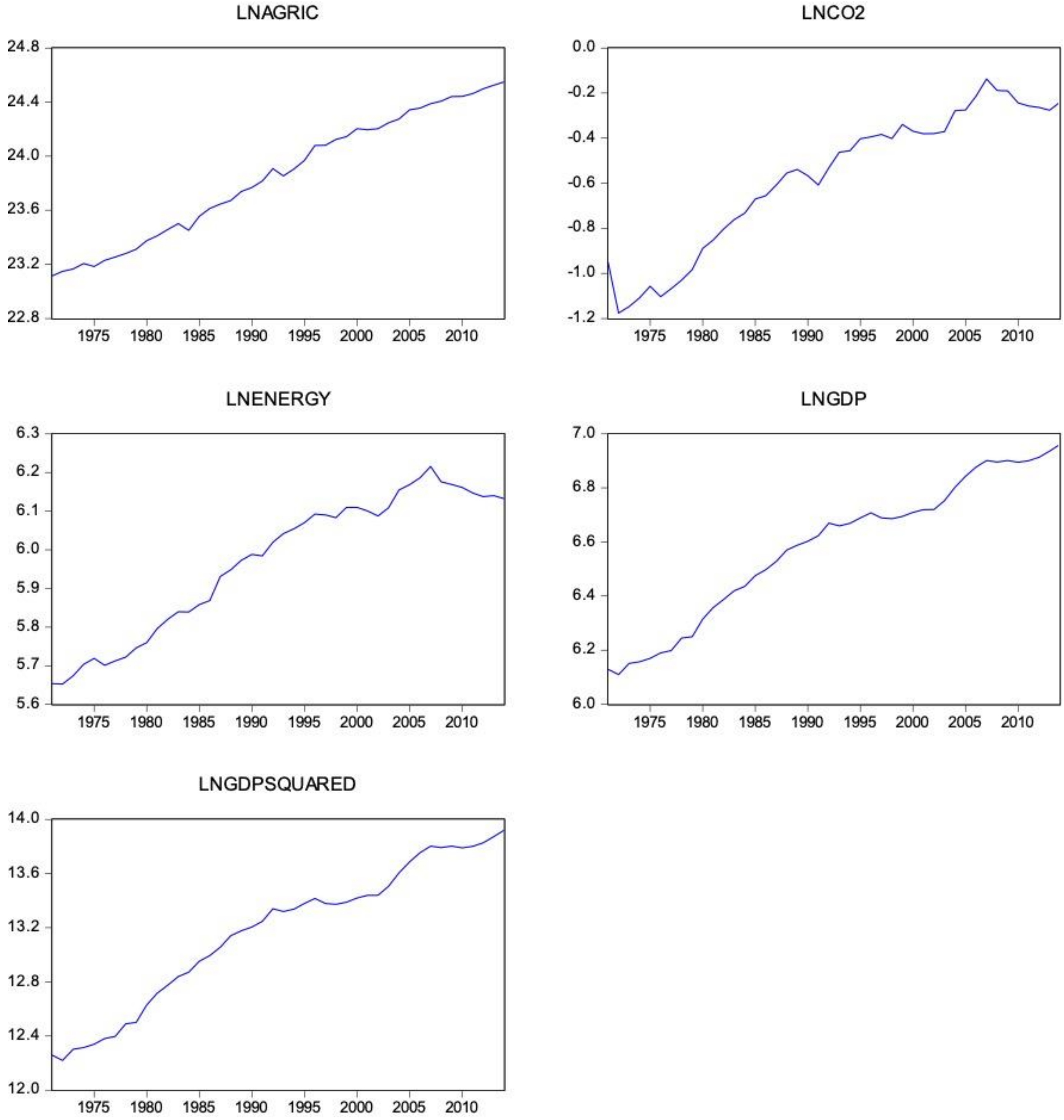

Figure 3: Graphical representation of the time paths of series in the model.

4.2. Econometric Model

In EKC hypothesis model, emissions per capita, emission intensity (emissions per GDP), level of pollution, and total emissions have all been employed as indicators for pollution, but per capita emissions more accurately characterize CO_2 emissions dynamics than the other indicators [114]. The basic EKC model highlights that environmental contamination indicators are dependent on GDP and GDPSQ, as most studies show [101]. The existence of the EKC hypothesis is assessed using CO_2 emissions (metric tons per capita), GDP per capita (constant 2010 US$ per capita), energy consumption (kg of oil equivalent per capita), and Agriculture, forestry, and fishing, value added [22,50,132]. Below is a description of the empirical relationship.

$$CO_{2_t} = (\,GDP_t\,, \mathrm{GDPSQ}_t\,, ENERG_t\,, AGRIC_t) \tag{1}$$

where CO_{2_t} represents CO_2 emissions (metric tons per capita), GDP_t shows the real gross domestic product per capita (constant 2010 US$), GDPSQ_t demonstrates the square of GDP_t, $ENERG_t$ presents energy consumption (kg of oil equivalent per capita), and $AGRIC_t$ represents Agriculture, forestry, and fishing, value added (constant 2010 US$).

The following is the explanation of the econometric model:

$$CO_{2_t} = \gamma_0 + \gamma_1 GDP_t + \gamma_2 \mathrm{GDPSQ}_t + \gamma_3 ENERG_t + \gamma_4 AGRIC_t + \varepsilon_t \tag{2}$$

For analysis, the linear model is changed into a natural log-linear model form, as most research, such as [157], show that this form produces more consistent and efficient findings. This is how the log-linear model is defined:

$$lnCO_{2_t} = \gamma_0 + \gamma_1 lnGDP_t + \gamma_2 ln\mathrm{GDPSQ}_t + \gamma_3 lnENERG_t + \gamma_4 lnAGRIC_t + \varepsilon_t \tag{3}$$

According to th theoretical approach for EKC hypothesis validity, the word ε_t represents the disturbance term of the regression, and the subscript 't' means the period. $\gamma_1$and γ_2 are expected to have positive and negative signs respectively. Because carbon emissions are positively correlated to energy consumption, the coefficient of $lnENERG_t$ is estimated to be positive ($\gamma_3 > 0$). The coefficient of $lnAGRIC_t$ can have a positive or negative sign ($\gamma_4 < 0\ or > 0$) as clear in literature that countries with sustainable agricultural practices and clean production technologies can decouple environmental degradation from agricultural productivity.

4.3. Testing for unit roots and structural break

Estimating the stationarity of a variable in time series data is critical for producing reliable conclusions since non-stationary variables produce inaccurate and false results. The Augmented Dickey-Fuller (ADF) by [158], Phillips Perron (PP) by [40], and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) by [159] tests were used to analyze the stationarity of the factors to avoid a false regression arising from non-stationary series [160]. These traditional unit root tests do not account for the issue of structural discontinuities in time series variables. Because the research study spans 35 years, the presence of structural breakdowns during that time cannot be ignored because it can lead to inaccurate results [50]. As a result, standard test results may be wrong [40].

In this work, the unit root test by [41], which analyzes one structural break, was utilized to address the structural break issue. The ZA unit root test was used to assess the date of structural break in the dependent variable, which was included in the model to address structural changes that could alter the estimation results.

4.4. ARDL Bound test of cointegration

With 35 total observations (1971–2014), the autoregressive distributed lag (ARDL) approach described by [161] was used. Unlike the standard models of Granger (1981) and Engle and Granger (1987), the ARDL model of cointegration is applicable to variables with varying integration orders [161], [162]. The estimation methods for short-run and long-run variables are consistent in this model. [162]. When only one cointegrating vector exists, Johansen and Juselius' (1990) cointegration approach is ineffective. Whether the underlying variables are I(0), I(1) or a mixture of both, the ARDL technique to cointegration or limits testing for a long-run relationship becomes essential. The sequence should not be integrated higher than the first order in this model [163]. As a result, the ARDL is the best cointegration strategy for this study in terms of producing realistic and efficient estimates.

In contrast to Johansen and Juselius's (1990) cointegration approach, the ARDL method of cointegration detects the cointegrating vector (s). To put it another way, each of the underlying variables can be thought of as a separate long-run relationship equation. The reparametrized result shows the short-run dynamics (conventional ARDL) as well as the long-run relationship of a single model's variables [162]. In the distributed lag model, the unrestricted lag of the regressors is included in the regression function. Given an endogenous variable, the ARDL approach to cointegration determines whether the model's variables are cointegrated or not, however it cannot be used when there are several cointegrating vectors [162], [164].

Because of these advantages, the ARDL model was chosen above other cointegration approaches. Estimating the long-term link between **CO₂**, GDP, **GDPSQ**, ENERG, and AGRIC requires two steps. The first step is to determine whether all of the series in the equation have a long-term link. After a long-term link has been established, the ARDL model is used to calculate long- and short-term coefficients. To estimate the cointegration relationship, the authors recreated Eq (1) using [161] limits test.

$$\begin{aligned} \Delta lnCO_{2t} &= \vartheta_0 + \vartheta_1 DU_t + \sum_{i=1}^{k} \delta_{1i}\, \Delta lnCO_{2t-i} + \sum_{i=0}^{k} \delta_{2i}\, \Delta lnGDP_{t-i} + \sum_{i=0}^{k} \delta_{3i}\, \Delta ln\mathrm{GDPSQ}_{t-i} \\ &+ \sum_{i=0}^{k} \delta_{4i}\, \Delta lnENERG_{t-i} + \sum_{i=0}^{k} \delta_{5i}\, \Delta lnAGRIC_{t-i} + \omega_1 lnCO_{2t-1} + \omega_2 lnGDP_{t-i} \\ &+ \omega_3 ln\mathrm{GDPSQ}_{t-i} + \omega_4 lnENERG_{t-i} + \omega_5 lnAGRIC_{t-i} + u_t \qquad (4) \end{aligned}$$

Where Δ , k and t demonstrates the first difference operator, optimal lag length and time respectively; ϑ_0 shows the constant term and ϑ_1 represents the structural break date (dummy variable). The dummy for the structural break is obtained from the break year from the ZA unit root test indicating a specified break point. ω demonstrates the coefficients of the long-run estimates; δ expresses the short-run coefficients; and the error term is represented by u_t. The null hypothesis of no-cointegration, $\mathrm{H}_0: \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5$ was examined against the alternative hypothesis of cointegration, $\mathrm{H}_1: \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5$. The null hypothesis was tested using the ARDL bound test. The Schwarz information criterion (SIC) was used to calculate the appropriate lag length (k). The F-statistic is used to test the null hypothesis's validity. The F statistic calculated from the model is compared using two critical values taken from [161] and [165], I(0) for the lower limit and I(1) for the higher limit. If the F-statistic generated from the model falls below the critical values of the lower bounds, the null hypothesis is not rejected. This shows that the variables are not cointegrated. If the F-statistic value falls between the critical values of the lower and upper boundaries, the test result is inconclusive. The null hypothesis of no cointegration is rejected if the F-statistic computed from the model exceeds the upper boundaries critical values of the tabulated F-statistics by [161] and [165]. As a result, the option of the variables in the model having a long-run relationship is accepted. After cointegration between the series has been established, the unrestricted error correction model is given to determine the model's convergence from the short to the long run, as well as the speed of adjustment. The short-run form of the error correction model can be tested using the specification indicated in equation (5) below once the long-run coefficients have been calculated.

$$\Delta InCO_{2t} = \vartheta_0 + \vartheta_1 DU_t + \sum_{i=1}^{k} \delta_{1i}\,\Delta lnCO_{2t-i} + \sum_{i=0}^{k} \delta_{2i}\,\Delta lnGDP_{t-i} + \sum_{i=0}^{k} \delta_{3i}\,\Delta ln\mathrm{GDPSQ}_{t-i} + \sum_{i=0}^{k} \delta_{4i}\,\Delta lnENERG_{t-i} + \sum_{i=0}^{k} \delta_{5i}\,\Delta lnAGRIC_{t-i} + \O ECT_{t-i} + u_t \qquad (5)$$

In this model, Ø demonstrates the coefficient of the error correction term (ECT) representing the speed of adjustment and ECT_{t-i} explains the error correction term. The coefficient of ECT_{t-i} (Ø) must produce statistically significant negative coefficient and in a stable model without fluctuations, the value should not be greater than 1 [166].

4.5. Diagnostic and Robustness tests

To assess the robustness of the estimates, the Breusch-Godfrey LM test (autocorrelation), Breusch-Pagan test (heteroscedasticity), ARCH test, Ramsey RESET test (misspecification of the functional form), and Jarque–Bera test (normality) were used. To determine any structural changes in the models, the cumulative sum of squares (CUSUMSQ) and the cumulative sum (CUSUM) were used to test their stability. If the CUSUM and CUSUMSQ values are inside the critical boundaries at a 5% level of significance, the model is stable.

4.6. Causality test

After cointegration was demonstrated, a causality test was used to determine the directions of the relationships between the variables. The Granger and Toda-Yamamoto causality tests, developed by [167] and [43], are widely used in the literature. The Granger causality test requires that the series in the model be stationary, and for variables that are not stationary, the first difference is employed. If the series have cointegration, one or more direction causal relationships should exist between them. However, the Toda and Yamamoto (1995) causality test, which is based on the vector autoregressive (VAR) model, employs series values at their level rather than the stationarity constraint that the Granger causality test requires. The series' maximum degree of integration(d) is estimated and added to the optimal lag length ($k+d_{\max}$) once the optimal lag(k) is determined. Finally, the modified Wald test (MWald) is used to evaluate whether there are any causal links between the series [43]. The Toda-Yamamoto causality test was estimated using the variables in the model, as indicated in Equation (6).

$$\begin{bmatrix} \ln CO_2 \\ \ln GDP \\ \ln GDPSQ \\ \ln ENERG \\ \ln AGRIC \end{bmatrix} = \begin{bmatrix} \delta \\ \theta \\ \lambda \\ \sigma \\ \varphi \end{bmatrix} + \sum_{i=1}^{k} \begin{bmatrix} b_{11i} & b_{12i} & b_{13i} & b_{14i} & b_{15i} \\ b_{21i} & b_{22i} & b_{23i} & b_{24i} & b_{25i} \\ b_{31i} & b_{32i} & b_{33i} & b_{34i} & b_{35i} \\ b_{41i} & b_{42i} & b_{43i} & b_{44i} & b_{45i} \\ b_{51i} & b_{52i} & b_{53i} & b_{54i} & b_{55i} \end{bmatrix} \begin{bmatrix} \ln CO_{2t-i} \\ \ln GDP_{t-i} \\ \ln GDPSQ_{t-i} \\ \ln ENERG_{t-i} \\ \ln AGRIC_{t-i} \end{bmatrix}$$

$$+ \sum_{j=k+1}^{d_{max}} \begin{bmatrix} b_{11j} & b_{12j} & b_{13j} & b_{14j} & b_{15j} \\ b_{21j} & b_{22j} & b_{23j} & b_{24j} & b_{25j} \\ b_{31j} & b_{32j} & b_{33j} & b_{34j} & b_{35j} \\ b_{41j} & b_{42j} & b_{43j} & b_{44j} & b_{45j} \\ b_{51j} & b_{52j} & b_{53j} & b_{54j} & b_{55j} \end{bmatrix} \begin{bmatrix} \ln CO_{2t-j} \\ \ln GDP_{t-j} \\ \ln GDPSQ_{t-j} \\ \ln ENERG_{t-j} \\ \ln AGRIC_{t-j} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \end{bmatrix} \quad (6)$$

5. Result and Discussions

5.1 Descriptive Analysis and Pearson Correlation

Table II: Descriptive summary

Variables	LNAGRIC	LN CO_2	LNENERGY	LNGDP	LNGDPSQ
Mean	23.85202	-0.575119	5.968985	6.581644	13.16329
Median	23.87868	-0.497145	6.030447	6.664061	13.32812
Maximum	24.54891	-0.137435	6.215472	6.960573	13.92115
Minimum	23.11464	-1.176418	5.652401	6.110083	12.22017
Std. Dev.	0.465696	0.313605	0.180364	0.262827	0.525655
Skewness	-0.094711	-0.528918	-0.431997	-0.377529	-0.377529
Kurtosis	1.611215	1.969695	1.699916	1.915063	1.915063
Jarque-Bera	3.601776	3.997668	4.467292	3.203200	3.203200
Pearson correlations of the variables					
LNAGRIC	1				
LNCO$_2$	0.967***	1			
LNENERG	0.975***	0.987	1		
LNGDP	0.984***	0.985***	0.983***	1	
LNGDPSQ	0.984***	0.985***	0.983***	01.000***	1

Table II shows the descriptive analysis and Pearson correlations for all of the variables utilized in the study. Because all of the variables were not normally distributed, the actual values were transformed into natural logarithm form and used in the descriptive analysis. The Pearson correlation matrix shows that GDP and GDPSQ have substantial positive associations with CO_2, whereas ENERG and CO_2 have positive relationship. There is a positive association between all of the variables. The descriptive and Pearson correlation analyses provide only a limited amount of information on the exact relationships between the variables, necessitating additional econometric analysis to quantify the link.

5.2 Unit root test

The empirical analysis begins with the unit root test. The series in the model must not be second-order stationary (I(2)) when using the ARDL approach. The stationarity of the variables used in this study and the results provided in Table III were tested using the ADF, PP, and KPSS tests, which are routinely used to test stationarity of macroeconomic series.

Except for CO_2 and AGRIC, all of the variables have a unit root or are non-stationary in their level. As a result, we performed a first-order differencing analysis, and the unit root test statistics revealed that the null hypothesis of non-stationary could be rejected for all of the series at the 5% and 1% levels of significance. As a result, all series are stationary or I (1) variables at the first difference.

Because the ADF test is characterized by low power and size distortions in such instances, the presence of structural breaks in series influences the stationarity results [40]. The Zivot and Andrews (1992) test was employed to handle this econometric problem since it accounts for the occurrence of one endogenous structural break in only intercept, only trend, or both intercept and trend. In the presence of structural breakdowns, the ZA test results show that all of the series in the model are stationary at their first differences (I(1)), as shown in Table IV. In addition, the dates for the series' breaks are decided. In the intercept and trend model, the break date for CO_2 is given as 2004. This date marks the start of an era in which Pakistan's economic growth was stable and a development momentum was induced [168]. After the break date, the ARDL was used to investigate the agriculture-induced EKC hypothesis for Pakistan, and the order of integration of the variables was set to 1.

Table III: Augmented Dickey and Fuller (ADF) and Phillips, Perron (PP) unit root tests and KPSS unit root.

Variables	Augmented Dickey-Fuller (ADF)		Phillips Perron (PP)		Kwiatkowski–Phillips–Schmidt–Shin (KPSS)	
	LEVEL	FIRST DIFFERECE	LEVEL	FIRST DIFFERENCE	LEVEL	FIRST DIFFERENCE
LN$\mathbf{CO_2}$	-1.808[0]	-8.947***[0]	-2.173[3]	-9.035***[1]	0.181**[5]	0.120*[0]
LNGDP	-0.995[0]	-5.969***[0]	-1.303[3]	-5.982***[2]	0.173*[5]	0.075[3]
LNGDPSQ	-1.581[1]	-5.749***[0]	-1.452[3]	-5.754***[1]	0.164**[5]	0.072[3]
LNENERG	0.349[0]	-5.768***[0]	0.243[1]	-5.769**[1]	0.195**[5]	0.135*[0]
LNAGRIC	-2.262[0]	-8.541***[0]	-2.262[0]	-8.982***[0]	0.142*[5]	0.150**[16]

Table IV: Results of Zivot and Andrews (ZA) structural break unit root test.

Variables	Zivot and Andrews (ZA) statistics at level			Zivot and Andrews (ZA) at statistics first difference		
	Intercept	Trend	Intercept and Trend	Intercept	Trend	Intercept and Trend
LN$\mathbf{CO_2}$	-4.251[0]	-5.842[0]	-5.485[0]	-4.316[4]	-4.182[4]	-4.741**[4]
Break year	1980	1989	1990	2004	2007	2004
LNGDP	-3.651***[2]	-4.074**[2]	-4.144***[2]	-6.677**[0]	-5.976*[0]	-6.609**[0]
Break year	1980	1989	1993	1993	1999	2003
LNGDPSQ	-3.617**[2]	-3.995**[2]	-4.222***[2]	-6.677**[0]	-5.976*[0]	-6.609**[0]
Break year	1980	1989	1997	1993	1999	2003
LNENERG	-1.314**[0]	-2.403**[0]	-2.311[0]	-6.260*[0]	-6.209*[0]	-6.292**[0]
Break year	1987	1997	1992	2007	1988	2003
LNAGRIC	-3.503[0]	-4.316***[0]	-4.940***[0]	-9.262**[0]	-9.164[0]	-9.257*[0]
Break year	1989	2001	1996	1985	1987	1997

5.3 ARDL Bounds Test of Cointegration

The long-run connection between CO_2 emissions and the covariates employed in each of the models is examined using the Bounds test approach after the variables are tested to be stationary at their first differences. The maximum lag length of 2 was determined using the VAR model, as indicated in Table V. The year 2004, which marked the start of stable economic growth, was included as a dummy variable in the ARDL model when the dependent variable's break date was considered in the ZA unit root test.

Table VI shows the results of the ARDL bound test of cointegration. The derived f-test statistic's result (10.29299) for the model is greater than the upper bound's 10%, 5%, and 1% Pesaran critical values, as well as the upper bound's 10% and 5% Narayan critical values. This study shows that there is a significant long-run link between $lnCO2_{\mathrm{t}}.$, $lnGDP_t$, $ln\mathrm{GDPSQ}_t$, $lnENE_t$, and $lnAGRIC_t$ and the null hypothesis of no cointegration is rejected at the 5% significance level for both the Pesaran (2001) and Narayan (2005) upper critical bounds. The Breusch–Pagan–Godfrey test for heteroscedasticity, the Breusch–Godfrey LM test for serial correlation, the Jarque–Bera test for normalcy, and the Ramsey Reset test for misspecification of functional form were all passed by the model.

Table V: Lag length selection criteria for cointegration.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	87.01327	NA	0.001022	-4.050664	-3.797332	-3.959067
1	90.98618	6.555289*	0.000882*	-4.199309*	-3.903755*	-4.092446*
2	91.16972	0.293660	0.000920	-4.158486	-3.820710	-4.036357
3	92.11091	1.458850	0.000925	-4.155545	-3.775548	-4.018150
4	92.18128	0.105563	0.000972	-4.109064	-3.686844	-3.956403

Table VI: ARDL Bounds test for Cointegration results.

Cointegration	F-value	Significance	Pesaran critical values		Narayan critical values	
			1(0) Bound	1(1) Bound	1(0) Bound	1(1) Bound
Yes	10.29299***	10%	2.26	3.35	2.752	3.994
		5%	2.62	3.79	3.354	4.774
		1%	3.41	4.68	4.768	6.670

5.4 Long-Run and Short-Run Regression Results

To evaluate the effect of the variables on $\mathbf{CO_2}$ emissions, long-run and short-run regression analyses are undertaken after the cointegration connection between the variables is established. The SIC criterion was used to estimate the lag duration, and Figure 4 illustrates the model selection criteria graph, which indicates a lag structure that minimizes the SIC criterion as follows: (1,2,2,1,1,2). The results are shown in Table VII, with the long-run model estimates in the upper panel and the short-run model estimates in the lower panel, followed by the models' diagnostic tests. At a 5% level, the results reveal that GDP($\mathbf{GDPSQ}$) and energy consumption have a positive(negative) and statistically significant effect on $\mathbf{CO_2}$ emissions. The coefficient for GDP is 8.692301, indicating that a 1% increase in $\boldsymbol{lnGDP_t}$ will result in a 8.692301 percent increase in $\boldsymbol{lnCO_{2\mathrm{t}}}$. The coefficient for $\boldsymbol{ln}\mathbf{GDPSQ}_{\boldsymbol{t}}$ is -0.623457, indicating a 0.623457 percent decrease in $\boldsymbol{ln}\mathbf{CO2}$ when $\boldsymbol{ln}\mathbf{GDPSQUARED}_{\boldsymbol{t}}$ increases by 1% holding other factors constant. In Pakistan, this finding strongly supports the agriculture-induced EKC hypothesis. As a result, in Pakistan, $\mathbf{CO_2}$ and economic growth have an inverse u-shaped relationship. These findings of a valid EKC theory is in line with the agriculture-induced EKC investigations of [22,50,132] as well as general EKC studies by [101–104,106–112,143,157,169–173]. The enormous increase in Pakistan's energy consumption, which is known to fuel economic growth through many sectors, explains the significant increase in emissions over time. Most consumers of renewable energy, particularly in the commonly utilized hydroelectric power generation, suffer numerous issues as a result of variations, hence Pakistan's energy industry is dominated by fossil fuel usage. The country's economic activities are mostly based on fossil fuels, particularly the usage of oil and coal, both of which contribute significantly to the country's emissions. As more attention is paid to health and the environment, increased economic growth, indicated by a square in GDP, provides the chance to invest in environmentally beneficial companies that use clean energy in production. Pakistan, as a developing country, prioritizes economic expansion and industrialization over environmental protection. At the high-income level indicated by **GDPSQ**, the government can impose strict environmental rules, raise environmental consciousness, and make significant advancements in the energy system to reduce $\mathbf{CO_2}$ emissions and pollution. The negative impact of **GDPSQ** on emissions is explained by this institutional quality. A negative association between agriculture value-added and $\mathbf{CO_2}$ emissions at the 10% level of significance is a noteworthy empirical conclusion in this study. A 1% increase in agriculture value-added results in a 0.00922 percent decrease in $\mathbf{CO_2}$ emissions in the long run. The lack of attention paid to sustainable agricultural practices in Pakistan explains the negative impact of agriculture value-added on $\mathbf{CO_2}$ emissions. Most farmers are highly motivated to generate large yields in order to increase their incomes, with little regard for the environmental consequences of their farming practices and inadequate management. The findings of [174,50] Confirms the results. The findings of [22, 132, 105, 26 ,142] demonstrates the nature of agricultural output in Pakistan. Unlike most affluent and north African countries, agricultural production in Pakistan is dominated by rudimentary methods, with farmers relying on farming practices and management aimed at increasing yields with little or no regard for environmental impact.

Table VII: ARDL cointegrating and long run form.

Panel 1: Long Run Coefficients				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
lnGDP	8.692301**	3.569788	2.434963	0.0205
lnGDPSQ	-0.623457**	0.282253	-2.208854	0.0342
ln**ENERG**	0.983535***	0.261478	3.761441	0.0007
lnAGRIC	-0.009224	0.121383	-0.075994	0.9399
Dum2004	0.071434*	0.041586	1.717754	0.0952
C	-36.411577***	12.635963	-2.881583	0.0069
Panel 2: Short Run Coefficients				
D(lnGDP)	18.405838***	6.080188	3.027182	0.0048
D(lnGDPSQ)	-1.381583***	0.472164	-2.926065	0.0062
D(ln**ENERG**)	1.305926***	0.306580	4.259664	0.0002
D(lnAGRIC)	-0.006325	0.083123	-0.076095	0.9398
D(Dum2004)	0.048983*	0.029127	1.681699	0.1021
CointEq(-1)	-0.685710***	0.106484	-6.439577	0.0000
R-squared	0.810008			
Adjusted R-squared	0.758192			
S.E. of regression	0.026598			
F-statistic	15.63239			
Prob(F-statistic)	0.000000			
Durbin-Watson statistic	1.529082			

*, ** and *** indicate 10%, 5% and 1% levels of significance respectively

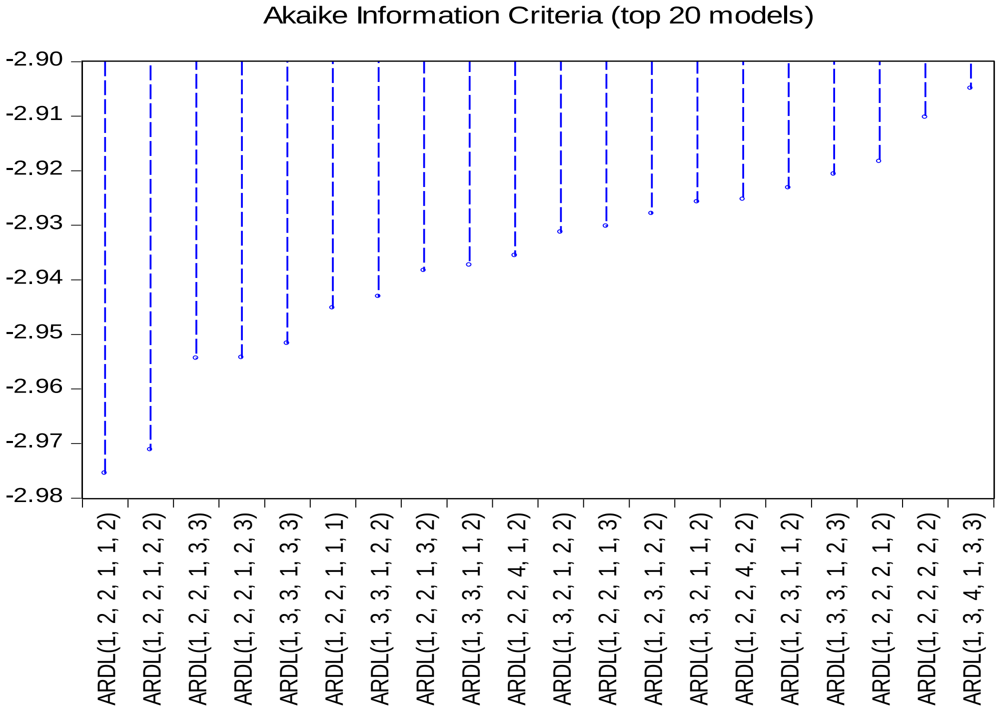

Figure 4: ARDL model selection criteria graph.

5.5 Diagnostics tests

Table VIII displays the diagnostic tests of the estimations used to demonstrate the results' robustness. Breusch-Godfrey LM, Breusch-Pagan-Godfrey, Ramsey RESET, and Jarque–Bera tests were all passed by the models. The findings indicate that the model is correctly defined, with no serial correlation, heteroscedasticity, and normally distributed residuals. The cumulative sum plots (CUSUM and CUSUMSQ) were used to ensure that the estimated model was stable over time and that no structural fractures were visible. CUSUM and CUSUMQ plots are shown in Figures 5 and 6, respectively, to test the model's stability. Both plots are within the critical bound of the 5% significance level, showing that the model is stable.

Table VIII: ARDL diagnostic tests results.

Test	$\chi 2$	Probability	Result
Jarque-Bera (Normality)	0.999	0.607	Residual is normally distributed
Breusch-Pagan-Godfrey (Heteroscedasticity)	0.958	0.490	No heteroscedasticity
Breusch-Godfrey (Serial correlation LM test)	1.804	0.181	No serial correlation
Ramsey Reset test (Functional form)	0.9323	0.358	Model is correctly specified
CUSUM (Stability)			Stable
CUSUM^2 (Stability)			Stable

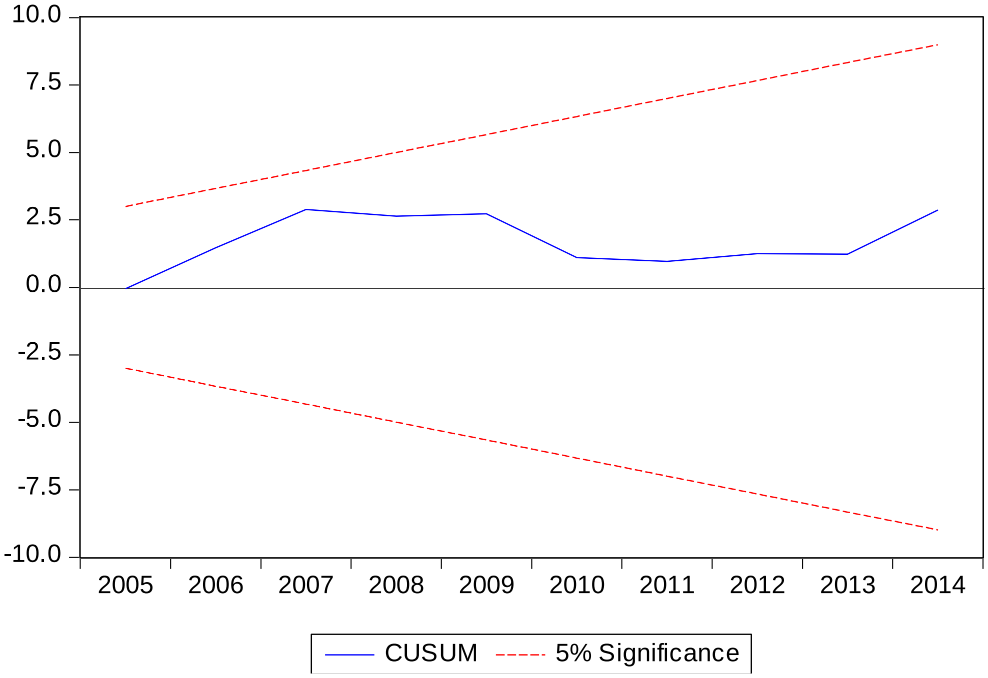

Figure 5: A plot of Cumulative Sum of Recursive Residuals (CUSUM) for the model.

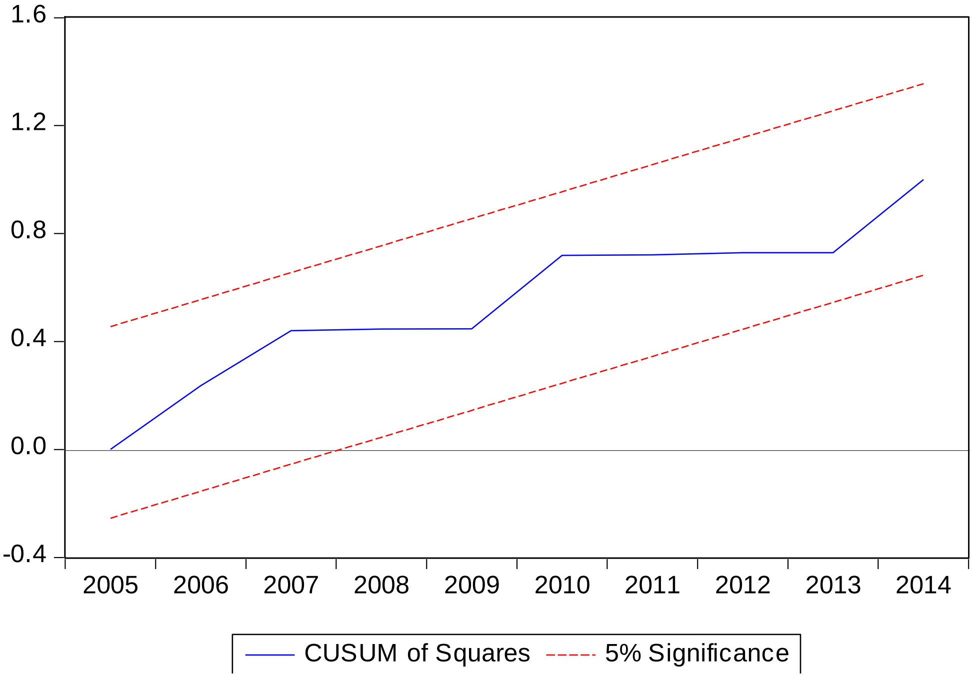

Figure 6: A plot of Cumulative Sum of Squares of Recursive Residuals (CUSUMSQ).

5.7 Granger Causality test

After the ARDL result showed the existence of a long-run relationship but offered no information on the direction of the long-term relationship among the variables, the Toda-Yamamoto (1995) causality test was used to investigate the direction of the link. Table IX shows that a long-run unidirectional causation exists between

GDP, GDPSQ and long-run CO_2 emissions, as determined by the Toda-Yamamoto (1995) causality test. The long-run unidirectional causal relationship between AGRIC, GDPSQ and GDP demonstrates the importance of the agricultural sector to Pakistan's economic growth and vice versa. The notion of Pakistan's energy-dependent economic growth is supported by the bidrectional long-run causal link between energy consumption and GDP.

Table IX: Toda and Yamamoto Granger causality analysis.

Dependent Variable	$\ln CO_2$	lnGDP	lnGDPSQ	ln**ENERG**	lnAGRIC
$\ln CO_2$	-	7.9753** (0.018)	7.5581** (0.0228)	0.1322 (0.9360)	1.0603 (0.5885)
lnGDP	0.0898 (0.9561)	-	12.1778*** (0.0023)	6.0788** (0.0479)	7.7092** (0.0212)
lnGDPSQ	0.0586 (0.9711)	12.1046*** (0.0024)	-	5.8139** (0.0546)	8.0827*** (0.0176)
lnENERG	0.7796 (0.6772)	6.6032** (0.0368)	6.5880** (0.0371)	-	0.5913 (0.7440)
lnAGRIC	0.4180 (0.8114)	0.3328 (0.8467)	0.3535 (0.8380)	1.2319 (0.5401)	-

6. Conclusions

The viability of the agriculture-induced EKC hypothesis in Pakistan was investigated using evidence from an ARDL approach with a structural break. CO_2 per capita emissions were the dependent variable, while GDP per capita, GDP per capita squared, energy consumption, and agriculture value-added were the independent factors. The study in hand employed time series data ranging from 1971 to 2014. Estimation methods included descriptive analysis, conventional and ZA unit root tests, autoregressive distributed lag model (ARDL) limits test of cointegration, and causality tests. With a positive link discovered between GDP, GDP SQUARE, and CO_2 emissions, the error correction model verified the presence of the agriculture-induced EKC hypothesis in Pakistan. The assumption of Pakistan's energy-dependent economic growth is further confirmed by the birectional long-run causal relationship between energy consumption and GDP, according to this study. The results of the Toda-yamamoto causality test demonstrate a unidirectional causality from GDP and GDP SQUARE to CO_2 emissions, but a unidirectional long-term causality from GDPSQ and agriculture value-added to CO_2 emissions. The bidirectional and unidirectional causal links between the two variables and GDP confirmed the importance of agriculture and energy consumption in economic growth.

The conclusions of this study have important policy implications for the environment. Because Pakistan's economy is strongly reliant on non-renewable energy, particularly fossil fuels, which is a major source of emissions, the government should implement clean energy policies that increase the use of renewable energy sources such as wind, natural gas, hydropower, and solar energy. Clean energy will reduce emissions by shifting away from non-renewable energy sources and toward renewable energy, which will enhance economic growth without raising emissions. This can be accomplished by providing tax incentives and subsidies to nuclear power facilities and the renewable energy sector to stimulate the usage of clean energy.

The importance of agriculture to the economy, as well as the damage it poses to the environment, has been highlighted by the findings of this study. As a result, the government and politicians must devise and implement methods that promote long-term agricultural practices without limiting productivity. Sustainable farming practices can be achieved by empowering a transition from rudimentary to advanced mechanized and environmentally friendly sustainable production systems. As the agriculture industry is recognized as an important area for CO_2 mitigation, policies in the sector must address aspects that allow for unsustainable farming practices. Credit limitations, improved agricultural inputs, technical efficiency due to unequal access to training and know-how, extension and veterinary services, and markets are among them. Crop and livestock research at the national and institutional levels must be encouraged in order to create long-term strategies for decoupling rising agricultural productivity from rising carbon emissions. Finally, other economic sectors such as the service sector, which contributes significantly to economic growth at a low environmental cost due to low energy consumption and pollution, should be given greater attention in order to strengthen these sectors and achieve the required economic growth.

This study can help agriculture-dominated developing nations establish effective strategies to attain low-carbon economies, as well as future empirical investigations on the relationship between agricultural production and carbon emissions.

Acknowledgements

This paper and the research behind it would not have been possible without the exceptional support and guidance of my supervisor from China (Professor Li Houjian), my mentor from Pakistan Dr Abdul Saboor, my friend Gideon Ntim-Amo from Ghana, my sister Ayesha Ali from UK and my beloved husband Hassaan bin Jalil from Pakistan.

Professor Li Houjian, my supervisor at Sichuan Agricultural university, has always looked over my research and answered with unfailing patience. Dr Abdul Saboor, my mentor has always been there with creative ideas to make my research unique and has always supported me like my father. My friend Gideon Ntim-Amo is a blessing from God who has been supporting me throughout my grad life and has helped me in correcting my mistakes and with data analysis, I have learned a lot from him. My sister Aisha Ali instead been busy in her own research helped me throughout my research and she also helped me in grammatical errors. My dearly husband Hassaan bin Jalil who is a gift of my elder's prayers helped me in formatting and mistakes. Last but not the least I want to thank my parents for their patience and living alone during my 3 years research in China.

References

[1] V. Alcántara and E. Padilla, "Analysis of CO2 and its explanatory factors in the different areas of the world," in *Technical report*, Universidad Autonoma de Barcelona, Department of Economics Applied Spain, 2005.

[2] IPCC, "Change, IPCC Climate. 'Synthesis Report. Contribution of working groups I.' II and III to the fifth assessment report of the intergovernmental panel on climate change 151.10.1017 (2014).," *Contrib. Work. Gr. III to Fifth Assess. Rep. Intergov. Panel Clim. Chang.*, vol. 1454, 2014.

[3] M. A. Culture, W. Franklin, and M. Steiner, “World Bank Publications Available,” *Water Int.*, vol. 10, no. 2, pp. 85–85, 1985, doi: 10.1080/02508068508686315.

[4] G. Bölük and M. Mert, “The renewable energy, growth and environmental Kuznets curve in Turkey: an ARDL approach,” *Renew. Sustain. Energy Rev.*, vol. 52, pp. 587–595, 2015.

[5] S. Kuznets, “Economic growth and income inequality,” *Am. Econ. Rev.*, vol. 45, no. 1, pp. 1–28, 1955.

[6] G. M. Grossman and A. B. Krueger, “Environmental Impacts of a North American Free Trade Agreement, Garber P.(éd.), The US-Mexico Free Trade Agreement.” MIT Press, Cambridge, MA, 1993.

[7] A. Rehman *et al.*, “Economic perspectives of major field crops of Pakistan: An empirical study,” *Pacific Sci. Rev. B Humanit. Soc. Sci.*, vol. 1, no. 3, pp. 145–158, 2015.

[8] T. Panayotou, “Empirical tests and policy analysis of environmental degradation at different stages of economic development,” International Labour Organization, 1993.

[9] N. Shafik and S. Bandyopadhyay, *Economic growth and environmental quality: time-series and cross-country evidence*, vol. 904. World Bank Publications, 1992.

[10] J. T. Roberts and P. E. Grimes, “Carbon intensity and economic development 1962–1991: A brief exploration of the environmental Kuznets curve,” *World Dev.*, vol. 25, no. 2, pp. 191–198, 1997.

[11] A. H. Akram-Lodhi, “(Re) imagining agrarian relations? The world development report 2008: Agriculture for development,” *Dev. Change*, vol. 39, no. 6, pp. 1145–1161, 2008.

[12] K. O. Fuglie, “Total factor productivity in the global agricultural economy: Evidence from FAO data,” *shifting patterns Agric. Prod. Product. Worldw.*, pp. 63–95, 2010.

[13] K. Fuglie and A. Nin-Pratt, “Global food policy report: a changing global harvest,” *Retrieved May*, vol. 20, p. 2013, 2012.

[14] C. P. Timmer, “Agricultural trade policy during structural transformation,” *Evol. Struct. world Agric. trade*, p. 39, 2009.

[15] A. Wood, “World Trade Report 2014–Trade and Development: Recent Trends and the Role of the WTOWorld Trade Organization, 2014,” *World Trade Rev.*, vol. 14, no. 3, pp. 546–548, 2015.

[16] K. Deininger and D. Byerlee, *Rising global interest in farmland: can it yield sustainable and equitable benefits?* World Bank Publications, 2011.

[17] M. Maertens and J. Swinnen, “Agricultural trade and development: a supply chain perspective, geneva:

World Trade Organization (WTO)," forthcoming Working Paper, 2014.

[18] G. C. Bertram, "The state of food and agriculture, 1966.," *Eugen. Rev.*, vol. 59, no. 2, pp. 73–74, 1967, doi: 10.1097/00010694-196510000-00017.

[19] D. Pimentel, "Impacts of organic farming on the efficiency of energy use in agriculture," *An Org. Cent. state Sci. Rev.*, pp. 1–40, 2006.

[20] I. B. Tabar, A. Keyhani, and S. Rafiee, "Energy balance in Iran's agronomy (1990–2006)," *Renew. Sustain. Energy Rev.*, vol. 14, no. 2, pp. 849–855, 2010.

[21] IPCC, "Impacts - Technical Summary," *Clim. Chang. 2014 Impacts, Adapt. Vulnerability. Part A Glob. Sect. Asp. Contrib. Work. Gr. II to Fifth Assess. Rep. Intergov. Panel Clim. Chang.*, pp. 35–94, 2014.

[22] K. K. Gokmenoglu and N. Taspinar, "Testing the agriculture-induced EKC hypothesis: the case of Pakistan," *Environ. Sci. Pollut. Res.*, vol. 25, no. 23, pp. 22829–22841, 2018.

[23] S. Tokgoz *et al.*, "Bottlenecks, drought, and oil price spikes: Impact on US ethanol and agricultural sectors," *Appl. Econ. Perspect. policy*, vol. 30, no. 4, pp. 604–622, 2008.

[24] G. Hochman, D. Rajagopal, and D. Zilberman, "The effect of biofuels on crude oil markets," 2010.

[25] F. Alluvione, B. Moretti, D. Sacco, and C. Grignani, "EUE (energy use efficiency) of cropping systems for a sustainable agriculture," *Energy*, vol. 36, no. 7, pp. 4468–4481, 2011.

[26] N. Dogan, "Agriculture and Environmental Kuznets Curves in the case of Turkey: evidence from the ARDL and bounds test," *Agric. Econ.*, vol. 62, no. 12, pp. 566–574, 2016.

[27] O. Tutulmaz, "Environmental Kuznets curve time series application for Turkey: why controversial results exist for similar models?," *Renew. Sustain. Energy Rev.*, vol. 50, pp. 73–81, 2015.

[28] J. Baek, "Environmental Kuznets curve for CO2 emissions: the case of Arctic countries," *Energy Econ.*, vol. 50, pp. 13–17, 2015.

[29] J. Baek and H. Kim, "Trade liberalization, economic growth, energy consumption and the environment: Time series evidence from G-20 economies," *J. East Asian Econ. Integr.*, vol. 15, no. 1, 2011.

[30] S. M. De Bruyn, J. C. J. M. van den Bergh, and J. B. Opschoor, "Economic growth and emissions: reconsidering the empirical basis of environmental Kuznets curves," *Ecol. Econ.*, vol. 25, no. 2, pp. 161–175, 1998.

[31] A. Aslan, M. A. Destek, and I. Okumus, "Bootstrap rolling window estimation approach to analysis of

the Environment Kuznets Curve hypothesis: evidence from the USA," *Environ. Sci. Pollut. Res.*, vol. 25, no. 3, pp. 2402–2408, 2018.

[32] J. Balaguer and M. Cantavella, "The role of education in the Environmental Kuznets Curve. Evidence from Australian data," *Energy Econ.*, vol. 70, pp. 289–296, 2018.

[33] S. Farhani, A. Chaibi, and C. Rault, "CO2 emissions, output, energy consumption, and trade in Tunisia," *Econ. Model.*, vol. 38, pp. 426–434, 2014.

[34] S. Katircioglu and A. Celebi, "Testing the role of external debt in environmental degradation: empirical evidence from Turkey," *Environ. Sci. Pollut. Res.*, vol. 25, no. 9, pp. 8843–8852, 2018.

[35] L. Lau, C. Choong, and Y. Eng, "Investigation of the environmental Kuznets curve for carbon emissions in Malaysia : Do foreign direct investment and trade matter ?," *Energy Policy*, vol. 68, pp. 490–497, 2014, doi: 10.1016/j.enpol.2014.01.002.

[36] A. Robalino-López, J.-E. García-Ramos, A. A. Golpe, and Á. Mena-Nieto, "System dynamics modelling and the environmental Kuznets curve in Ecuador (1980–2025)," *Energy Policy*, vol. 67, pp. 923–931, 2014.

[37] M. Wagner, "The carbon Kuznets curve: a cloudy picture emitted by bad econometrics?," *Resour. Energy Econ.*, vol. 30, no. 3, pp. 388–408, 2008.

[38] D. I. Stern, M. S. Common, and E. B. Barbier, "Economic growth and environmental degradation: the environmental Kuznets curve and sustainable development," *World Dev.*, vol. 24, no. 7, pp. 1151–1160, 1996.

[39] E. Dijkgraaf and H. R. J. Vollebergh, "A test for parameter homogeneity in CO 2 panel EKC estimations," *Environ. Resour. Econ.*, vol. 32, no. 2, pp. 229–239, 2005.

[40] P. Perron, "Testing for a unit root in a time series with a changing mean," *J. Bus. Econ. Stat.*, vol. 8, no. 2, pp. 153–162, 1990.

[41] E. Zivot and D. W. K. Andrews, "Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis," *J. Bus. Econ. Stat.*, vol. 20, no. 1, pp. 25–44, 2002.

[42] D. Maki, "Tests for cointegration allowing for an unknown number of breaks," *Econ. Model.*, vol. 29, no. 5, pp. 2011–2015, 2012.

[43] H. Y. Toda and T. Yamamoto, "Statistical inference in vector autoregressions with possibly integrated processes.," *J. Econom.*, vol. 66, pp. 225–250, 1995.

[44] S. Abu-Bader and A. S. Abu-Qarn, "Financial development and economic growth: empirical evidence

from six MENA countries," *Rev. Dev. Econ.*, vol. 12, no. 4, pp. 803–817, 2008.

[45] W. Bank, *World development indicators 2014*. The World Bank, 2014.

[46] M. M. Rafique and S. Rehman, "National energy scenario of Pakistan–Current status, future alternatives, and institutional infrastructure: An overview," *Renew. Sustain. Energy Rev.*, vol. 69, pp. 156–167, 2017.

[47] F. M. Mirza and A. Kanwal, "Energy consumption, carbon emissions and economic growth in Pakistan: Dynamic causality analysis," *Renew. Sustain. Energy Rev.*, vol. 72, pp. 1233–1240, 2017.

[48] F. Plassmann and N. Khanna, "Household income and pollution: implications for the debate about the environmental Kuznets curve hypothesis," *J. Environ. Dev.*, vol. 15, no. 1, pp. 22–41, 2006.

[49] M. Shahbaz and A. Sinha, "Environmental Kuznets Curve for CO2 Emission: A Literature Survey, MPRA Paper." 2018.

[50] K. K. Gokmenoglu, N. Taspinar, and M. Kaakeh, "Agriculture-induced environmental Kuznets curve: the case of China," *Environ. Sci. Pollut. Res.*, vol. 26, no. 36, pp. 37137–37151, 2019.

[51] E. Dogan and R. Inglesi-Lotz, "The impact of economic structure to the environmental Kuznets curve (EKC) hypothesis: evidence from European countries," *Environ. Sci. Pollut. Res.*, pp. 1–8, 2020.

[52] S. Dietz and W. N. Adger, "Economic growth, biodiversity loss and conservation effort," *J. Environ. Manage.*, vol. 68, no. 1, pp. 23–35, 2003.

[53] T. Seppälä, T. Haukioja, and J. KAIvo-ojA, "The EKC hypothesis does not hold for direct material flows: environmental Kuznets curve hypothesis tests for direct material flows in five industrial countries," *Popul. Environ.*, vol. 23, no. 2, pp. 217–238, 2001.

[54] A. Acaravci and I. Ozturk, "On the relationship between energy consumption, CO2 emissions and economic growth in Europe," *Energy*, vol. 35, no. 12, pp. 5412–5420, 2010.

[55] R. T. Carson, "The environmental Kuznets curve: seeking empirical regularity and theoretical structure," *Rev. Environ. Econ. Policy*, 2020.

[56] M. A. Cetin, "Investigating the environmental Kuznets curve and the role of green energy: emerging and developed markets," *Int. J. Green Energy*, vol. 15, no. 1, pp. 37–44, 2018.

[57] M. Zilio and M. Recalde, "GDP and environment pressure: the role of energy in Latin America and the Caribbean," *Energy Policy*, vol. 39, no. 12, pp. 7941–7949, 2011.

[58] E. S. Osabuohien, U. R. Efobi, and C. M. W. Gitau, "Beyond the environmental Kuznets curve in

Africa: evidence from panel cointegration," *J. Environ. Policy Plan.*, vol. 16, no. 4, pp. 517–538, 2014.

[59] A. Sinha and M. Shahbaz, "Estimation of environmental Kuznets curve for CO2 emission: role of renewable energy generation in India," *Renew. energy*, vol. 119, pp. 703–711, 2018.

[60] J. Yang and B. Chen, "Carbon footprint estimation of Chinese economic sectors based on a three-tier model," *Renew. Sustain. Energy Rev.*, vol. 29, pp. 499–507, 2014.

[61] N. Ç. Yavuz, "CO2 emission, energy consumption, and economic growth for Turkey: evidence from a cointegration test with a structural break," *Energy Sources, Part B Econ. Planning, Policy*, vol. 9, no. 3, pp. 229–235, 2014.

[62] U. Al-Mulali and I. Ozturk, "The effect of energy consumption, urbanization, trade openness, industrial output, and the political stability on the environmental degradation in the MENA (Middle East and North African) region," *Energy*, vol. 84, pp. 382–389, 2015, doi: 10.1016/j.energy.2015.03.004.

[63] Z. Zoundi, "CO2 emissions, renewable energy and the Environmental Kuznets Curve, a panel cointegration approach," *Renew. Sustain. Energy Rev.*, vol. 72, pp. 1067–1075, 2017.

[64] I. A. VILLANUEVA, "Introducing institutional variables in the environmental Kuznets curve (EKC): a Latin American study," *Ann. Ser.*, vol. 1, pp. 71–81, 2012.

[65] S. M. De Bruyn and R. J. Heintz, "The environmental Kuznets curve hypothesis. Handbook of Environmental and resource economics," *ed. JCJM van den Bergh, Edward Elgar, Cheltenham UK, Northampt. MA, USA*, 1999.

[66] N. Apergis and J. E. Payne, "CO2 emissions, energy usage, and output in Central America," *Energy Policy*, vol. 37, no. 8, pp. 3282–3286, 2009.

[67] K. H. Ghali and M. I. T. El-Sakka, "Energy use and output growth in Canada: a multivariate cointegration analysis," *Energy Econ.*, vol. 26, no. 2, pp. 225–238, 2004.

[68] A. Jalil and M. Feridun, "The impact of growth, energy and financial development on the environment in China: a cointegration analysis," *Energy Econ.*, vol. 33, no. 2, pp. 284–291, 2011.

[69] M. Nasir and F. U. Rehman, "Environmental Kuznets curve for carbon emissions in Pakistan: an empirical investigation," *Energy Policy*, vol. 39, no. 3, pp. 1857–1864, 2011.

[70] M. Shahbaz, N. Khraief, G. S. Uddin, and I. Ozturk, "Environmental Kuznets curve in an open economy: a bounds testing and causality analysis for Tunisia," *Renew. Sustain. Energy Rev.*, vol. 34, pp. 325–336, 2014.

[71] M. A. Zambrano-Monserrate, C. Carvajal-Lara, and R. Urgiles-Sanchez, "Is there an inverted U-shaped

curve? Empirical analysis of the Environmental Kuznets Curve in Singapore," *Asia-Pacific J. Account. Econ.*, vol. 25, no. 1–2, pp. 145–162, 2018.

[72] S. Zhang, "Is trade openness good for environment in South Korea? The role of non-fossil electricity consumption," *Environ. Sci. Pollut. Res.*, vol. 25, no. 10, pp. 9510–9522, 2018.

[73] H. H. Lean and R. Smyth, "CO2 emissions, electricity consumption and output in ASEAN," *Appl. Energy*, vol. 87, no. 6, pp. 1858–1864, 2010.

[74] B. Saboori and J. Sulaiman, "Environmental degradation, economic growth and energy consumption: Evidence of the environmental Kuznets curve in Malaysia," *Energy Policy*, vol. 60, pp. 892–905, 2013.

[75] S. Katircioglu, "Investigating the role of oil prices in the conventional EKC model: evidence from Turkey," *Asian Econ. Financ. Rev.*, vol. 7, no. 5, pp. 498–508, 2017.

[76] A. K. Richmond and R. K. Kaufmann, "Energy prices and turning points: the relationship between income and energy use/carbon emissions," *Energy J.*, vol. 27, no. 4, 2006.

[77] S. T. Katircioğlu, "Testing the tourism-induced EKC hypothesis: The case of Singapore," *Econ. Model.*, vol. 41, pp. 383–391, 2014.

[78] J. Balaguer and M. Cantavella, "Estimating the environmental Kuznets curve for Spain by considering fuel oil prices (1874–2011)," *Ecol. Indic.*, vol. 60, pp. 853–859, 2016.

[79] A. Latif, A. S. Shakir, and M. U. Rashid, "Appraisal of economic impact of zero tillage, laser land levelling and bed-furrow interventions in Punjab, Pakistan," *Pakistan J. Eng. Appl. Sci.*, 2016.

[80] U. Al-Mulali, B. Saboori, and I. Ozturk, "Investigating the environmental Kuznets curve hypothesis in Vietnam," *Energy Policy*, vol. 76, pp. 123–131, 2015.

[81] S. Katircioğlu and S. Katircioğlu, "Testing the role of urban development in the conventional environmental Kuznets curve: evidence from Turkey," *Appl. Econ. Lett.*, vol. 25, no. 11, pp. 741–746, 2018.

[82] J. B. Ang, "CO2 emissions, energy consumption, and output in France," *Energy Policy*, vol. 35, no. 10, pp. 4772–4778, 2007.

[83] N. Apergis and I. Ozturk, "Testing environmental Kuznets curve hypothesis in Asian countries," *Ecol. Indic.*, vol. 52, pp. 16–22, 2015.

[84] A. Jalil and S. F. Mahmud, "Environment Kuznets curve for CO2 emissions: a cointegration analysis for China," *Energy Policy*, vol. 37, no. 12, pp. 5167–5172, 2009.

[85] U. K. Pata, “The effect of urbanization and industrialization on carbon emissions in Turkey: evidence from ARDL bounds testing procedure,” *Environ. Sci. Pollut. Res.*, vol. 25, no. 8, pp. 7740–7747, 2018.

[86] M. Shahbaz, I. Ozturk, T. Afza, and A. Ali, “Revisiting the environmental Kuznets curve in a global economy,” *Renew. Sustain. energy Rev.*, vol. 25, pp. 494–502, 2013.

[87] J. R. Vincent, “Testing for environmental Kuznets curves within a developing country,” *Environ. Dev. Econ.*, pp. 417–431, 1997.

[88] T. M. Selden and D. Song, “Neoclassical growth, the J curve for abatement, and the inverted U curve for pollution,” *J. Environ. Econ. Manage.*, vol. 29, no. 2, pp. 162–168, 1995.

[89] M. P. Lucas and I. M. Pabuayon, “Lucas Agri Devt,” vol. 8, no. 2, pp. 61–77, 2011.

[90] S. Saint Akadiri, T. T. Lasisi, G. Uzuner, and A. C. Akadiri, “Examining the causal impacts of tourism, globalization, economic growth and carbon emissions in tourism island territories: bootstrap panel Granger causality analysis,” *Curr. Issues Tour.*, vol. 23, no. 4, pp. 470–484, 2020.

[91] S. Saint Akadiri, A. A. Alola, G. Olasehinde-Williams, and M. U. Etokakpan, “The role of electricity consumption, globalization and economic growth in carbon dioxide emissions and its implications for environmental sustainability targets,” *Sci. Total Environ.*, vol. 708, p. 134653, 2020.

[92] M. K. Khan, M. I. Khan, and M. Rehan, “The relationship between energy consumption, economic growth and carbon dioxide emissions in Pakistan,” *Financ. Innov.*, vol. 6, no. 1, pp. 1–13, 2020.

[93] O. B. Awodumi and A. O. Adewuyi, “The role of non-renewable energy consumption in economic growth and carbon emission: Evidence from oil producing economies in Africa,” *Energy Strateg. Rev.*, vol. 27, p. 100434, 2020, doi: 10.1016/j.esr.2019.100434.

[94] J. Zhang, Z. Fan, Y. Chen, J. Gao, and W. Liu, “Decomposition and decoupling analysis of carbon dioxide emissions from economic growth in the context of China and the ASEAN countries,” *Sci. Total Environ.*, p. 136649, 2020.

[95] Q. Wang and M. Su, “Drivers of decoupling economic growth from carbon emission–an empirical analysis of 192 countries using decoupling model and decomposition method,” *Environ. Impact Assess. Rev.*, vol. 81, p. 106356, 2020.

[96] J. Yang *et al.*, “Driving forces of China’s CO2 emissions from energy consumption based on Kaya-LMDI methods,” *Sci. Total Environ.*, vol. 711, p. 134569, 2020.

[97] X. Zheng *et al.*, “Drivers of change in China’s energy-related CO2 emissions,” *Proc. Natl. Acad. Sci.*, vol. 117, no. 1, pp. 29–36, 2020.

[98] A. Ibrahim, “Effects of energy consumption, economic growth and population growth on carbon dioxide emissions: a dynamic approach for African economies (1990-2011),” 2020.

[99] G. M. Grossman and A. B. Krueger, “Environmental impacts of a North American free trade agreement,” National Bureau of Economic Research, 1991.

[100] C. F. Tang and E. C. Tan, “Does tourism effectively stimulate Malaysia’s economic growth?,” *Tour. Manag.*, vol. 46, pp. 158–163, 2015.

[101] U. Al-Mulali, S. A. Solarin, and I. Ozturk, “Investigating the presence of the environmental Kuznets curve (EKC) hypothesis in Kenya: an autoregressive distributed lag (ARDL) approach,” *Nat. Hazards*, vol. 80, no. 3, pp. 1729–1747, 2016, doi: 10.1007/s11069-015-2050-x.

[102] S. A. Sarkodie and I. Ozturk, “Investigating the environmental Kuznets curve hypothesis in Kenya: a multivariate analysis,” *Renew. Sustain. Energy Rev.*, vol. 117, p. 109481, 2020.

[103] G. N. Ike, O. Usman, and S. A. Sarkodie, “Testing the role of oil production in the environmental Kuznets curve of oil producing countries: New insights from Method of Moments Quantile Regression,” *Sci. Total Environ.*, vol. 711, p. 135208, 2020.

[104] Q. Chen and D. Taylor, “Economic development and pollution emissions in Singapore: Evidence in support of the Environmental Kuznets Curve hypothesis and its implications for regional sustainability,” *J. Clean. Prod.*, vol. 243, p. 118637, 2020.

[105] M. Ben Jebli and S. Ben Youssef, “The role of renewable energy and agriculture in reducing CO2 emissions: Evidence for North Africa countries,” *Ecol. Indic.*, vol. 74, pp. 295–301, 2017.

[106] A. Kacprzyk and Z. Kuchta, “Shining a new light on the environmental Kuznets curve for CO2 emissions,” *Energy Econ.*, vol. 87, p. 104704, 2020.

[107] H. Rahman, A. Ghazali, G. A. Bhatti, and S. U. Khan, “Role of Economic Growth, Financial Development, Trade, Energy and FDI in Environmental Kuznets Curve for Lithuania: Evidence from ARDL Bounds Testing Approach,” *Eng. Econ.*, vol. 31, no. 1, pp. 39–49, 2020.

[108] M. Ben Jebli, S. Ben Youssef, and I. Ozturk, “Testing environmental Kuznets curve hypothesis: The role of renewable and non-renewable energy consumption and trade in OECD countries,” *Ecol. Indic.*, vol. 60, pp. 824–831, 2016.

[109] T. Li, Y. Wang, and D. Zhao, “Environmental Kuznets curve in China: new evidence from dynamic panel analysis,” *Energy Policy*, vol. 91, pp. 138–147, 2016.

[110] N. M. Suki, A. Sharif, S. Afshan, and N. M. Suki, “Revisiting the Environmental Kuznets Curve in Malaysia: The role of globalization in sustainable environment,” *J. Clean. Prod.*, p. 121669, 2020.

[111] S. T. Katircioğlu and N. Taşpinar, “Testing the moderating role of financial development in an environmental Kuznets curve: empirical evidence from Turkey,” *Renew. Sustain. Energy Rev.*, vol. 68, pp. 572–586, 2017.

[112] J. Baek, “A panel cointegration analysis of CO2 emissions, nuclear energy and income in major nuclear generating countries,” *Appl. Energy*, vol. 145, pp. 133–138, 2015.

[113] S. Özokcu and Ö. Özdemir, “Economic growth, energy, and environmental Kuznets curve,” *Renew. Sustain. Energy Rev.*, vol. 72, pp. 639–647, 2017.

[114] H. Şentürk, T. Omay, J. Yildirim, and N. Köse, “Environmental Kuznets Curve: Non-Linear Panel Regression Analysis,” *Environ. Model. Assess.*, pp. 1–19, 2020.

[115] V. G. R. C. Govindaraju and C. F. Tang, “The dynamic links between CO2 emissions, economic growth and coal consumption in China and India,” *Appl. Energy*, vol. 104, pp. 310–318, 2013.

[116] K. M. Day and R. Q. Grafton, “Growth and the environment in Canada: An empirical analysis,” *Can. J. Agric. Econ. Can. d’agroeconomie*, vol. 51, no. 2, pp. 197–216, 2003.

[117] S. Erdogan, I. Okumus, and A. E. Guzel, “Revisiting the Environmental Kuznets Curve hypothesis in OECD countries: the role of renewable, non-renewable energy, and oil prices.,” *Environ. Sci. Pollut. Res. Int.*, 2020.

[118] O. A. Onafowora and O. Owoye, “Bounds testing approach to analysis of the environment Kuznets curve hypothesis,” *Energy Econ.*, vol. 44, pp. 47–62, 2014.

[119] C.-F. Ng, C.-K. Choong, and L.-S. Lau, “Environmental Kuznets curve hypothesis: asymmetry analysis and robust estimation under cross-section dependence,” *Environ. Sci. Pollut. Res.*, pp. 1–14, 2020.

[120] J. G. Wu, Y. S. Cui, and H. L. Shao, “The analysis on impact of the input of agricultural film material to the sustainable development of vegetable industry of Hebei-based on the environmental kuznets curve,” in *Applied Mechanics and Materials*, 2013, vol. 320, pp. 774–779.

[121] H. Hettige, M. Mani, and D. Wheeler, “Industrial pollution in economic development: the environmental Kuznets curve revisited,” *J. Dev. Econ.*, vol. 62, no. 2, pp. 445–476, 2000.

[122] M. S. Hervieux and O. Darné, “Production and consumption-based approaches for the environmental Kuznets curve using ecological footprint,” *J. Environ. Econ. Policy*, vol. 5, no. 3, pp. 318–334, 2016.

[123] G. De Vita, S. Katircioglu, L. Altinay, S. Fethi, and M. Mercan, “Revisiting the environmental Kuznets curve hypothesis in a tourism development context,” *Environ. Sci. Pollut. Res.*, vol. 22, no. 21, pp. 16652–16663, 2015.

[124] J. Gao, W. Xu, and L. Zhang, “Tourism, economic growth, and tourism-induced EKC hypothesis: evidence from the Mediterranean region,” *Empir. Econ.*, pp. 1–23, 2019.

[125] K. Zaman, M. Shahbaz, N. Loganathan, and S. A. Raza, “Tourism development, energy consumption and Environmental Kuznets Curve: Trivariate analysis in the panel of developed and developing countries,” *Tour. Manag.*, vol. 54, pp. 275–283, 2016.

[126] P. Adjei Kwakwa, H. Alhassan, and S. Aboagye, “Environmental Kuznets curve hypothesis in a financial development and natural resource extraction context: evidence from Tunisia,” 2018.

[127] N. Saleem and J. Z. Shujah-ur-Rahman, “The impact of human capital and biocapacity on environment: environmental quality measure through ecological footprint and greenhouse gases,” *J Pollut Eff Cont*, vol. 7, p. 237, 2019.

[128] M. A. Destek and S. A. Sarkodie, “Investigation of environmental Kuznets curve for ecological footprint: the role of energy and financial development,” *Sci. Total Environ.*, vol. 650, pp. 2483–2489, 2019.

[129] E. Dogan and B. Turkekul, “CO 2 emissions, real output, energy consumption, trade, urbanization and financial development: testing the EKC hypothesis for the USA,” *Environ. Sci. Pollut. Res.*, vol. 23, no. 2, pp. 1203–1213, 2016.

[130] H. R. Horee, S. A. Galali, and S. Gafare, “Examining the impact of financial development and energy consumption on the environmental degradation in Iran in the framework of the environmental kuznets curve hypothesis (EKC),” *Iran. Energy Econ.*, vol. 2, no. 6, pp. 27–48, 2013.

[131] M. W. Zafar, S. Saud, and F. Hou, “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.*, vol. 26, no. 13, pp. 13246–13262, 2019.

[132] I. B. Gurbuz, E. Nesirov, and G. Ozkan, “Does agricultural value-added induce environmental degradation? Evidence from Azerbaijan,” *Environ. Sci. Pollut. Res.*, pp. 1–14, 2020.

[133] Y. Li, L. Barton, and D. Chen, “Simulating response of N2O emissions to fertiliser N application and climatic variability from a rain-fed and wheat-cropped soil in Western Australia,” *J. Sci. Food Agric.*, vol. 92, no. 5, pp. 1130–1143, 2012.

[134] A. Bhatia, N. Jain, and H. Pathak, “Methane and nitrous oxide emissions from Indian rice paddies, agricultural soils and crop residue burning,” *Greenh. Gases Sci. Technol.*, vol. 3, no. 3, pp. 196–211, 2013.

[135] J. Garnier *et al.*, “Long-term changes in greenhouse gas emissions from French agriculture and livestock (1852–2014): From traditional agriculture to conventional intensive systems,” *Sci. Total Environ.*, vol. 660, pp. 1486–1501, 2019.

[136] T. Zhang, M. J. Wooster, D. C. Green, and B. Main, “New field-based agricultural biomass burning trace gas, PM2. 5, and black carbon emission ratios and factors measured in situ at crop residue fires in Eastern China,” *Atmos. Environ.*, vol. 121, pp. 22–34, 2015.

[137] R. S. Mohamad, V. Verrastro, L. Al Bitar, R. Roma, M. Moretti, and Z. Al Chami, “Effect of different agricultural practices on carbon emission and carbon stock in organic and conventional olive systems,” *Soil Res.*, vol. 54, no. 2, pp. 173–181, 2016.

[138] A. Ullah, D. Khan, I. Khan, and S. Zheng, “Does agricultural ecosystem cause environmental pollution in Pakistan? Promise and menace,” *Environ. Sci. Pollut. Res.*, vol. 25, no. 14, pp. 13938–13955, 2018, doi: 10.1007/s11356-018-1530-4.

[139] H. Qiao, F. Zheng, H. Jiang, and K. Dong, “The greenhouse effect of the agriculture-economic growth-renewable energy nexus: evidence from G20 countries,” *Sci. Total Environ.*, vol. 671, pp. 722–731, 2019.

[140] X. Liu, S. Zhang, and J. Bae, “The nexus of renewable energy-agriculture-environment in BRICS,” *Appl. Energy*, vol. 204, pp. 489–496, 2017.

[141] D. Burakov, “Does Agriculture Matter for Environmental Kuznets Curve in Russia: Evidence from the ARDL Bounds Tests Approach,” *AGRIS on-line Pap. Econ. Informatics*, vol. 11, no. 665-2019–4012, pp. 23–34, 2019.

[142] S. Ali *et al.*, “Climate Change and Its Impact on the Yield of Major Food Crops: Evidence from Pakistan,” *Foods*, vol. 6, no. 6, p. 39, 2017, doi: 10.3390/foods6060039.

[143] S. A. Sarkodie, “The invisible hand and EKC hypothesis: what are the drivers of environmental degradation and pollution in Africa?,” *Environ. Sci. Pollut. Res.*, vol. 25, no. 22, pp. 21993–22022, 2018.

[144] A. A. Chandio, W. Akram, F. Ahmad, and M. Ahmad, “Dynamic relationship among agriculture-energy-forestry and carbon dioxide (CO 2) emissions: empirical evidence from China,” *Environ. Sci. Pollut. Res.*, vol. 27, no. 27, pp. 34078–34089, 2020.

[145] M. Ben Jebli and S. Ben Youssef, “Renewable energy consumption and agriculture: evidence for cointegration and Granger causality for Tunisian economy,” *Int. J. Sustain. Dev. World Ecol.*, vol. 24, no. 2, pp. 149–158, 2017.

[146] M. Ben Jebli and S. Ben Youssef, “Renewable energy, arable land, agriculture, CO2 emissions, and economic growth in Morocco,” *MPRA Pap.*, no. 76798, 2017.

[147] M. Ben Jebli and S. Ben Youssef, “Combustible renewables and waste consumption, agriculture, CO2 emissions and economic growth in Brazil,” *Carbon Manag.*, vol. 10, no. 3, pp. 309–321, 2019.

[148] M. T. I. Khan, Q. Ali, and M. Ashfaq, “The nexus between greenhouse gas emission, electricity production, renewable energy and agriculture in Pakistan,” *Renew. Energy*, vol. 118, pp. 437–451, 2018.

[149] X. Liu, S. Zhang, and J. Bae, “The impact of renewable energy and agriculture on carbon dioxide emissions: Investigating the environmental Kuznets curve in four selected ASEAN countries,” *J. Clean. Prod.*, vol. 164, pp. 1239–1247, 2017.

[150] B. Lin and B. Xu, “Factors affecting CO2 emissions in China’s agriculture sector: A quantile regression,” *Renew. Sustain. Energy Rev.*, vol. 94, pp. 15–27, 2018.

[151] E. Zafeiriou and M. Azam, “CO2 emissions and economic performance in EU agriculture: Some evidence from Mediterranean countries,” *Ecol. Indic.*, vol. 81, pp. 104–114, 2017.

[152] A. A. G. Raeeni, S. Hosseini, and R. Moghaddasi, “How energy consumption is related to agricultural growth and export: An econometric analysis on Iranian data,” *Energy Reports*, vol. 5, pp. 50–53, 2019.

[153] L. Zhang, J. Pang, X. Chen, and Z. Lu, “Carbon emissions, energy consumption and economic growth: Evidence from the agricultural sector of China’s main grain-producing areas,” *Sci. Total Environ.*, vol. 665, pp. 1017–1025, 2019.

[154] S. L. Saravia-Matus, P. A. Hörmann, and J. A. Berdegué, “Environmental efficiency in the agricultural sector of Latin America and the Caribbean 1990–2015: are greenhouse gas emissions reducing while agricultural production is increasing?,” *Ecol. Indic.*, vol. 102, pp. 338–348, 2019.

[155] L. Zhangwei and Z. Xungangb, “Study on relationship between Sichuan agricultural carbon dioxide emissions and agricultural economic growth,” *Energy Procedia*, vol. 5, pp. 1073–1077, 2011.

[156] R. Waheed, D. Chang, S. Sarwar, and W. Chen, “Forest, agriculture, renewable energy, and CO2 emission,” *J. Clean. Prod.*, vol. 172, pp. 4231–4238, 2018.

[157] S. A. Solarin, U. Al-Mulali, I. Musah, and I. Ozturk, “Investigating the pollution haven hypothesis in Ghana: An empirical investigation,” *Energy*, vol. 124, pp. 706–719, 2017, doi: 10.1016/j.energy.2017.02.089.

[158] D. A. Dickey and W. A. Fuller, “Likelihood ratio statistics for autoregressive time series with a unit root,” *Econom. J. Econom. Soc.*, pp. 1057–1072, 1981.

[159] D. Kwiatkowski, P. C. B. Phillips, P. Schmidt, and Y. Shin, “Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root?,” *J. Econom.*, vol. 54, no. 1–3, pp. 159–178, 1992.

[160] C. W. J. Granger, P. Newbold, and J. Econom, “Spurious regressions in econometrics,” *Baltagi, Badi H. A Companion Theor. Econom.*, pp. 557–561, 1974.

[161] M. H. Pesaran, Y. Shin, and R. J. Smith, “Bounds testing approaches to the analysis of level relationships,” *J. Appl. Econom.*, vol. 16, no. 3, pp. 289–326, 2001.

[162] M. H. Pesaran and Y. Shin, “An autoregressive distributed-lag modelling approach to cointegration analysis,” *Econom. Soc. Monogr.*, vol. 31, pp. 371–413, 1998.

[163] S. Narayan and P. K. Narayan, “Determinants of demand for Fiji’s exports: an empirical investigation,” *Dev. Econ.*, vol. 42, no. 1, pp. 95–112, 2004.

[164] Emeka and A. Kelvin, “Autoregressive Distributed Lag (ARDL) cointegration technique: application and interpretation,” *J. Stat. Econom. Methods*, vol. 5, no. 3, pp. 63–91, 2016, doi: 10.1002/jae.616.

[165] P. K. Narayan, “The saving and investment nexus for China: evidence from cointegration tests,” *Appl. Econ.*, vol. 37, no. 17, pp. 1979–1990, 2005.

[166] P. K. Narayan and R. Smyth, “What determines migration flows from low-income to high-income countries? An empirical investigation of Fiji–Us migration 1972–2001,” *Contemp. Econ. Policy*, vol. 24, no. 2, pp. 332–342, 2006.

[167] C. W. J. Granger, “Investigating causal relations by econometric models and cross-spectral methods,” *Econom. J. Econom. Soc.*, pp. 424–438, 1969.

[168] Waheed, M. and Alam, T. and Ghauri, and S. Pervaiz, “Structural breaks and unit root: evidence from Pakistani macroeconomic time series Structural Breaks and Unit Root: Evidence from Pakistani Macroeconomic Time Series,” *MRPA Pap.*, no. 1797, 2006.

[169] M. Shahbaz, S. A. Solarin, and I. Ozturk, “Environmental Kuznets Curve hypothesis and the role of globalization in selected African countries,” *Ecol. Indic.*, vol. 67, pp. 623–636, 2016, doi: 10.1016/j.ecolind.2016.03.024.

[170] S. Aboagye, “Economic expansion and environmental sustainability nexus in Ghana,” *African Dev. Rev.*, vol. 29, no. 2, pp. 155–168, 2017.

[171] E. Abokyi, P. Appiah-Konadu, F. Abokyi, and E. F. Oteng-Abayie, “Industrial growth and emissions of CO2 in Ghana: the role of financial development and fossil fuel consumption,” *Energy Reports*, vol. 5, pp. 1339–1353, 2019.

[172] N. Ahmad, L. Du, J. Lu, J. Wang, H.-Z. Li, and M. Z. Hashmi, “Modelling the CO2 emissions and economic growth in Croatia: is there any environmental Kuznets curve?,” *Energy*, vol. 123, pp. 164–172, 2017.

[173] D. K. Twerefou, F. Adusah-Poku, and W. Bekoe, “An empirical examination of the Environmental Kuznets Curve hypothesis for carbon dioxide emissions in Ghana: an ARDL approach,” *Environ. Socio-economic Stud.*, vol. 4, no. 4, pp. 1–12, 2016.

[174] P. A. Owusu and S. Asumadu-Sarkodie, “Is there a causal effect between agricultural production and carbon dioxide emissions in Ghana?,” *Environ. Eng. Res.*, vol. 22, no. 1, pp. 40–54, 2017, doi: 10.4491/eer.2016.092.