frontiers | Frontiers in Energy Research

TYPE Original Research
PUBLISHED 25 November 2022
DOI 10.3389/fenrg.2022.1053234

Check for updates

Asymmetric effect of agriculture value added on CO2 emission: Does globalization and energy consumption matter for pakistan

Nabila Khurshid[1]*, Jamila Khurshid[2], Usman Shakoor[1] and Kashif Ali[1]

[1]Department of Economics, Comsats University, Islamabad, Pakistan, [2]Department of Business Administration, University of the Poonch, Rawalakot, Azad Kashmir

OPEN ACCESS

EDITED BY
Ezio Mancaruso,
Institute of Sciences and Technologies for Energy and Mobility, National Research Council (CNR), Italy

REVIEWED BY
Najabat Ali,
Hamdard University, Pakistan
Yue Dou,
University of International Business and Economics, China

*CORRESPONDENCE
Nabila Khurshid,
nabilakhurshid@comsats.edu.pk

SPECIALTY SECTION
This article was submitted to Carbon Capture, Utilization and Storage, a section of the journal Frontiers in Energy Research

RECEIVED 25 September 2022
ACCEPTED 31 October 2022
PUBLISHED 25 November 2022

CITATION
Khurshid N, Khurshid J, Shakoor U and Ali K (2022), Asymmetric effect of agriculture value added on CO2 emission: Does globalization and energy consumption matter for pakistan.
Front. Energy Res. 10:1053234.
doi: 10.3389/fenrg.2022.1053234

Globalization has resulted in several technical advancements, including the ability to connect people all over the world and drive the economies with higher agricultural output. With agricultural productivity expanding quickly, the negative impact of globalization on environmental degradation is being disregarded. Rapid agricultural expansion and globalization have resulted in significant increases in energy consumption and CO2 emissions. The primary purpose of this research is to assess the role of Pakistan's massive agriculture industry in encouraging or discouraging CO2 emissions under Globalization scenario. Therefore, we applied Non-linear Autoregressive Distributive Lag Nonlinear Autoregressive Distributed Lag model from 1971 to 2021. Our results showed that in presence of globalization, agricultural production shows asymmetries in case of positive and negative shocks. A positive shock in Agricultural production increased the CO2 emissions while negative shock in agricultural production decreased CO2 emissions. Furthermore, GDP, energy consumption and economic globalization have positive association with economic globalization while on the other hand, surprisingly trade and urbanization in the presence of globalization have negative association with CO2 emissions. Environmental deterioration due to greenhouse emissions causes climatic variation in the economy and several mitigation strategies are required on sustainable basis in Pakistan. So, our study recommends that farmers of Pakistan should adopt organic farming this will help to reduce CO2 emissions.

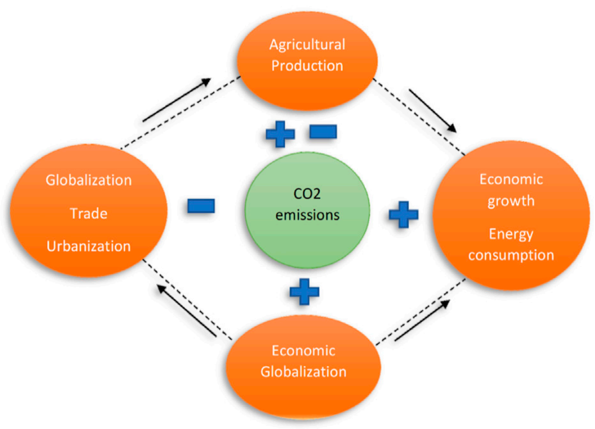
KEYWORDS

agricultural production, CO2 emissions, globalization, energy consumption, Pakistan

Introduction

Globalization has lately gained significance as countries have become more interdependent (Haseeb et al., 2018). The flow of commodities and services across nations has expanded as the amount of commerce has increased, and international contact has quickened. As a result, intense competition was built between countries.

10.3389/fenrg.2022.1053234



GRAPHICAL ABSTRACT

This has created a situation where countries are working hard to improve their well-being, as well as their physical and human capital (Shahbaz et al., 2016a). The degree of affluence in emerging nations has continuously improved, particularly in the last 2 decades (Sarkodie et al., 2019; Sarkodie and Strezov, 2018). This development has increased the demand for agricultural goods. Consequently, agricultural production has increased. In some nations, the first phases of agriculture include conventional grain production, which allows small farmers to earn a living. Nowadays only the economic crops and tourism in the rural sectors have been growing due to economic globalization which is a great step for this industry (Chen et al., 2019). But this has also caused a very serious impact on the biodiversity that once was found in these areas, the lack of knowledge about agriculture has adverse effects on biodiversity protection (Aswani et al., 2018). Economic globalization is a major source of pricing fluctuations and way of doing agricultural activities (Popp et al., 2018). This is detrimental to poorer people's food security, as well as the agricultural production chain and the economic system (Sokil et al., 2018; Lanfranchi et al., 2019). Swisher et al. (2018) concluded that economic globalization acts as the exact opposite of the major concepts of sustainable agriculture and farming, it causes stress on the local producers and reduces dependence on "nourishing" local economies. This lends credence to the claims that economic globalization is the primary source of income disparity, as well as the harmful influence of the agricultural sector on the environment (Iram and Fatima, 2008). Economic globalization has also led to damage to the environment due to an increase in agricultural production through technological innovations (Mariyakhan et al., 2020). Agricultural production mechanism involved energy consumption on large scale. When agricultural production increases due to globalization, demand for energy consumption is also increased. Energy consumption in developing nations is mostly based on nonrenewable energy sources, which contributes to increased greenhouse gas (GHG) emissions into the environment (Majeed and Luni 2019). As a result, agricultural growth has environmental consequences (Gokmenoglu and TaspinarPeyraud et al., 2014;, 2018; World Bank, 2007).

Global climate change has been increased as a result of this predicament. From 2015 through 2018, average annual temperatures were the highest in history, demonstrating the extent to which global warming has accelerated (World Meteorological Organization, 2017). GHG emissions continue to rise, hitting a new high in 2017; these emissions are the primary driver of global warming (Qiao et al., 2019; Wen et al., 2021). The levels of CO2, methane, and nitrogen oxide gas in the atmosphere increased to 405.5 parts per million (ppm), 1859 parts per billion (ppb), and 329.9 parts per billion (ppb), correspondingly (World Meteorological Organization, 2017). Increased concentrations of such pollutants have caused significant ecological destruction (IPCC, 2014). Moreover, CO2 is responsible for 70% of worldwide GHG emissions. Fossil fuels, which constitute about 80% of global energy use, has contributed to rising CO2 levels in the atmosphere (Yilanci and Pata, 2020). CO2 emissions were 35.6 billion metric tonnes in 2010, with a 7.6% increase to 43.2 billion metric tonnes by 2040 (IEA, 2016). This illness is directly affected by human activities (Baek, 2016). As a result, many academics are interested in the link between energy use and CO2 emissions. In 2018, global agricultural and related land use emissions were 9.3 billion tonnes of CO2 equivalent (Gt CO2eq). More than half of this amount was generated by crop and livestock activity at the farm gate. Crop and livestock emissions were 14 percent higher in 2018 than in 2000. As a result, total farm gate and land emissions from agriculture were around 4% lower in 2018 (Figure 1).

Even though agriculture is the largest source of CO2 emissions, the geographical spread and progress of agricultural CO2 emissions are important contributors to climate change (Lahiri Dutt, 2004; Muhammad et al., 2020). Agriculture accounts for 14% of worldwide CO2 emissions, with even higher percentages projected in the future. Carbon dioxide emissions from agriculture grew between 2010 and 2016. Total CO2 emissions from agricultural operations were 5088.7 Mt in 2010, and this figure has risen to 5285.5 Mt by 2016. Agriculture generates 24% of greenhouse gas emissions directly and 0.87% indirectly to the environment. Agriculturally based GHGs have serious environmental consequences since GHGs are the primary driver of climatic variations.

The agricultural sector is critical since it is a key source of revenue and labor in emerging regions, particularly in Pakistan. Pakistan's agricultural industry contributes 23% of GDP and employs 37% of the labor force, illustrating the importance of

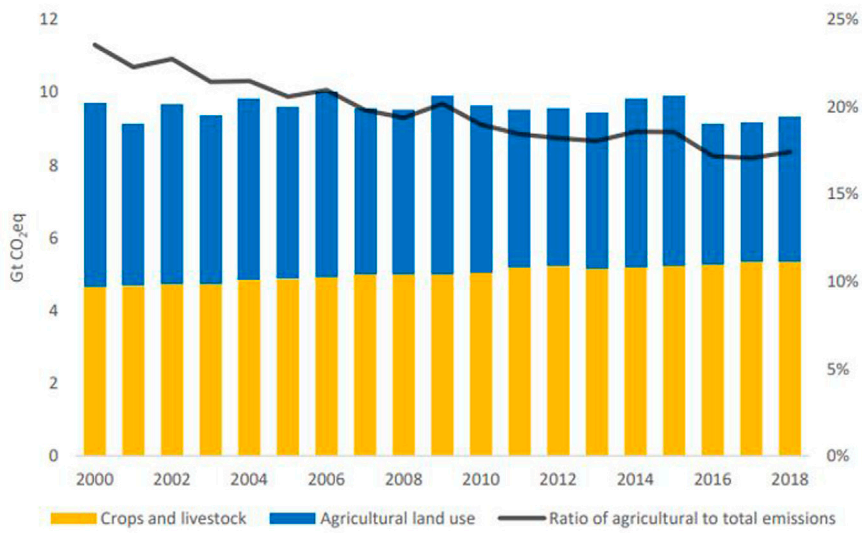


FIGURE 1
Annual emission levels from crops and animals, as well as associated land use, and agriculture's contribution to global GHG emissions from all sectors, 2000–2018 (Source: FAOSTAT, 2020)

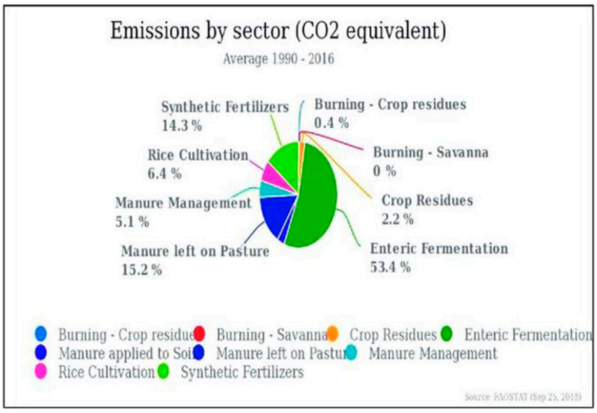


FIGURE 2
Total greenhouse gas emissions from the agriculture sector in Pakistan. Source: FAOSTAT, 2018.

agriculture to the country's economy. Rice is Pakistan's main crop, accounting for 6% of total pollution emissions, with agricultural soil contributing 2.1%. Poor water management, poor fertilizer applications, and a variety of agricultural practices all contribute to increased pollution. Following the 2008 National GHG Inventory, agriculture accounts for 39% of countrywide Carbon footprint in Pakistan (Khan et al., 2011). According to the Government of Pakistan (2017), agriculture is the second most significant contributor to GHG emissions. Furthermore, this sector is responsible for feeding billions of people worldwide. As a consequence, it exerts a significant effect on assessing global environmental quality. Figure 2 Shows the Contribution of different sub-sectors of agriculture in emission of CO2 in Pakistan.

Like other world globalization in Pakistan is also increasing after 1970 and this globalization affects the environmental quality of Pakistan. The increase in globalization is represented in Figure 3. Even though globalization affects environmental quality *via* many channels and agriculture is one prominent channel among them, but very little research has been done in this context. Globalization has created a situation in which finished products travel farther and more often around the world than ever before. Higher goods transportation can have several environmental consequences, including increased emissions and exotic species. This situation urges the researcher to conduct research on agricultural production, energy consumption, and CO2 emission in the globalization era.

This research study's major objective is to look into the relationships between Pakistan's agricultural output, energy use, economic expansion, and carbon dioxide emissions during globalization and economic globalization. Researchers from several fields concluded that increased crop production, non-renewable energy use, and economic development in industrialized nations are all contributing factors to environmental degradation. By modifying the model for agricultural production, energy consumption, economic growth, and CO2 emissions, this study will help to close the gap between earlier research. This study will offer policymakers a

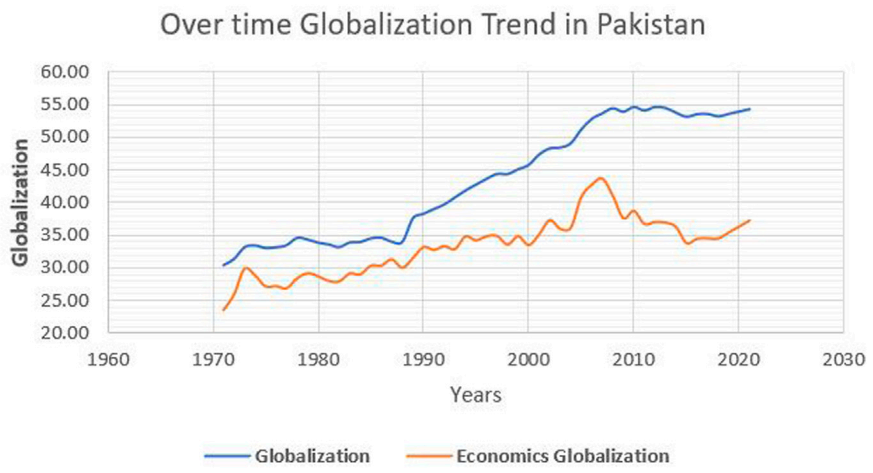


FIGURE 3
Trend of globalization in Pakistan.

fresh perspective on how to create important instruments for balancing environmental quality and economic growth. This research will also contribute whether economic globalization and globalization have any impact on carbon emission.

Several studies in Pakistan have used linear models to investigate Carbon footprints and their relationships to energy utilization, economic progress, agricultural intensification, organic fuel usage, green and renewable energy, economic and population growth, forest and agricultural production, and sustainable energy disposal. In this paper, we show how agricultural productivity and energy consumption affect CO2 emissions in Pakistan in a non-linear way in the face of globalization. The current study's findings will help Pakistan build policies to attain agricultural sustainability by considering the effects of globalization and implementing steps to decrease the negative environmental consequences of agricultural operations based on their degree of development. Furthermore, policy proposals were made to reduce the environmental effect of agriculture and animal production while ensuring output development. Finally, the research study offered approaches for Pakistan to participate to ecological sustainability based on its level of development. The following is the paper's format: Our investigation of current material is covered in the section on Related Material. The technique of the inquiry is covered in the section Methodology. The unit root tests, the Non-linear autoregressive distributed lag (NARDL) model, and an appraisal of long-run and short-run evidence are all included in the Results and Discussion section. The conclusion and recommendations section goes into the study's results as well as new policy solutions.

Some snippets from past literature

The amount of CO2 released is recognized as an important metric for monitoring environmental damage. Many empirical studies may be identified from the perspective of the agriculture business. Agriculture CO2 emissions and agriculture economic growth are inextricably linked. Asumadu-Sarkodie and Owusu (2017) investigated GHGs emissions and livestock productivity indices have very close link in Ghana from 1960 to 2013. By Liu et al. (2017) identified that renewable energy, agriculture, and environmental linkages in BRICS nations. CO2 emissions were shown to be increased by all causes, including agricultural output. Appiah et al. (2018) examined the association between the agricultural production and greenhouse gas emissions in designated emerging market economies between 1971 and 2014. Their findings revealed that a 1% raise in agricultural and livestock productivity resulted in a 28% rise in CO2 emissions. Gokmenoglu and Taspnar (2018) explored the link among CO2 emissions, income growth, energy consumption, and agribusiness in Pakistan. According to their results, agriculture was inelastic and positive influence on CO2 emissions. Perrier et al. (2019) investigated the impact of several factors on emissions reduction in Europe between 2009–2014. Their results showed that Agriculture-related greenhouse gas emissions grew in emerging nations while remaining stable in wealthy countries. Alkan and Binatl (2021) utilized the Structured Decomposition Method to examine the causes of growing CO2 emissions in Turkey. Using the Structured Decomposition Analysis technique, they examined the primary drivers of CO2 emissions variation during 5-year intervals from 1990 to 2015. According to the statistics, the variables of per capita spending and population increased

 10.3389/fenrg.2022.1053234

CO_2 emissions, however the emission coefficient factor lowered emissions. Other factors indicate the influence of the EU's unified approach on greenhouse gas emissions. When evaluating the growth of agribusiness within the context of the Common Agricultural Policy, Constantin et al. (2021) emphasized this point. Because of the use of the cross-sectional linear regression approach, they have been evaluated by environmental requirements and labor efficiency.

In comparison, there has been little study into renewable energy generation. Chen et al. (2019) evaluate Chinese data from 1980 to 2014 to find the link between renewable energy and CO_2 emissions. They claimed that using renewable energy decreased CO_2 emissions. Al-mulali et al. (2016) examined data from 58 industrialized and underdeveloped countries and discovered that renewable energy generation increased pollution.

Recently researcher added Agriculture and Globalization Index in their research work. Shahbaz et al. (2016b) investigated the impact of the globalization index on Turkey from 1970 to 2010. They concluded that globalization reduced CO_2 emissions. Shahbaz et al. (2017) discovered that globalization increases CO_2 emissions in Australia from 1970 to 2012. According to Paramati et al. (2017), globalization is increasing CO_2 emissions. Haseeb et al. (2018) explored whether globalization had a detrimental influence on CO_2 emissions in the BRICS countries. Leal and Marques (2020) investigated how globalization raises CO_2 emissions in certain nations while decreasing emissions in others. Globalization, according to Varsava (2003), has expedited the industrial growth in underdeveloped nations. Asongu and Odhiambo (2019) explored how trade openness enhances institution optimism, which is required to generate economic growth in developing nations. Globalization is a phenomenon with a hidden objective intended at starving emerging economies while benefitting wealthier nations. Whereas Rodrik et al. (2004); Saud et al., 2018 contend that globalization establishes a new entire globe architectural features in which widespread affects (i.e., manufacturing battlegrounds and global financial organizations) have as their primary goal enabling unrestricted competition and increasing possibilities for labors to increase their income.

Methodology

Theoretical framework

According to the theory of the scale of land management, indirect factors like natural catastrophes might have an impact on agricultural carbon emissions. Fiscal support for agriculture, farmers' per capita income, planting layout, pesticide input (Van der Werf, 1996) and agricultural machinery input are all discussed by Carroccio et al. (2016) and Trinh et al. (2021) in their study. The higher the land management scale, the larger the impacted agricultural area, and the greater the yield drop during the same natural catastrophe will result in a greater difference between the expected agricultural production and the actual yield. Farmers with bigger land management scales are more inclined to alter their original farming practices to make up for the "loss" brought on by natural disasters, which has an impact on agricultural carbon emissions. Farmers on a bigger land management scale focus more on preserving the land for sustainable usage in terms of financial support for agriculture. Soil-testing formula fertilizers and slow-release fertilizers can both benefit from subsidies in order to decrease the amount of chemicals required and improve use efficiency. Subsidies encourage the adoption of less hazardous and toxic agrochemicals, which lowers carbon emissions. A purchase incentive for agricultural equipment can also dramatically boost the investment intensity of farmers with larger business scales' machinery and equipment, encourage the use of fossil fuels, and raise carbon emissions. The desire of farmers to grow grain can be greatly increased by an increase in the direct grain and producer subsidies gained by farmers with a big planting scale, which will increase the area of grain planting and support a relative reduction in the carbon emissions of planting. Increases in per capita income can cause peasants with larger land management scales to have higher energy needs for agricultural production. Peasants' need for electricity, natural gas, and other energy sources for living and working will also rise at the same time. Agricultural carbon emissions will rise under the rigid conditions that the energy needs of the entire society are dominated by carbon-based energy. Due to their varied development characteristics, different crops require varying amounts of agricultural chemicals, such as insecticides and fertilizers. Food crops produce less carbon than cash crops, according to studies. As a result, carbon emissions tend to decline as the share of food crop operations scale rises. Peasants with bigger management scales are more likely to adopt new technologies like effective fertilization, which minimizes environmental pollution and carbon emissions while increasing the efficiency of chemical input requirements. The amount of input that agricultural technology requires impacts the scale of land management, which in turn influences agricultural carbon emissions. The scale of land management will become more extensive as a result of increased mechanization, which will speed up the consumption of energy sources like petroleum fuels and consequently raise carbon emissions. In conclusion, using agricultural machinery helps increase agricultural output efficiency while also somewhat lowering carbon emissions.

Data and its sources

We utilized data from World Development Indicators and the Government of Pakistan Economic Survey from 1971 to

10.3389/fenrg.2022.1053234

TABLE 1 Variable Description and Data sources.

Variable	Symbol	Definition	Data sources
Dependent variable			
Agricultural Production	Agr	Agricultural value added (% of GDP)	WDI
Independent Variables			
CO2 emission	CO2	CO2 emissions (kt)	WDI
GDP per capita	GDP	GDP per capita (constant 2015 US$)	WDI
Energy use	EC	Energy use (kg of oil equivalent per capita)	WDI
Trade	Trade	Trade (% of GDP)	WDI
Globalization	Koff	Globalization Index	KOFF
Urbanization	URB	Urban population (% of the total population)	WDI

2021. Table 1 shows the details of the variables employed in the current study:

Model specification

Agriculture, although a major cash sources but is also contributed to the increase in environmental degradation. At one hand, agriculture sector promoting economic growth but on the other hand, it also contributes to CO2 emissions and environmental degradation. The main aim of this study is to test whether agricultural sector could contribute to air pollution (carbon dioxide emission level) in Pakistan. In the literature, carbon dioxide is considered the main driver of air pollution and environmental quality. From this point of view, the following model is suggested in this study:

$$CO_2 = f\,(GDP, E, A, \mathrm{U}, \mathrm{T}, \mathrm{G}) \tag{1}$$

where CO2 denotes carbon dioxide emissions (kt), E represents energy consumption (kt of oil equivalent), GDP is real income, U represents urbanization, T represents trade, A stands for the agricultural proxy and G stands for Globalization.

Equation (2). Is used to measure the log-run relation of CO2 emission which is an expanded form of Eq. (1):

$$CO_2 = \delta_0 + \delta_1 Agr_t + \delta_2 GDP_t + \delta_3 EC_t + \delta_4 trade_t + \delta_5 KOFFI_t + \delta_6 URB_t + \varepsilon_t \tag{2}$$

where CO_2, denotes CO2 emissions, $\mathrm{Agr_t}$ denotes agricultural productivity, $\mathrm{GDP_t}$ denotes GDP per capita, $\mathrm{EC_t}$ denotes energy consumption, $\mathrm{Trade_t}$ denotes international trade, $KOFFI_t$ represent globalization, $\mathrm{Urb_t}$ denotes urban population, and ε_t is the error term. Respecify Eq. (1) above we get the ARDL Cointegration model equation as follows.

$$CO_{2t} = \delta_0 + \Sigma_{i=1}^{n}\eta_1\Delta Agr_{t-1} + \Sigma_{i=1}^{n}\eta_2\Delta GDP_{t-1} + \Sigma_{i=1}^{n}\eta_3\Delta EC_{t-1} + \Sigma_{i=1}^{n}\eta_4\Delta Trade_{t-1} + \Sigma_{i=1}^{n}\eta_5\Delta KOFFI_{t-1} + \Sigma_{i=1}^{n}\eta_6\Delta URB + \delta_1 Agr_{t-1} + \delta_2 GDP_{t-1} + \delta_3 EC_{t-1} + \delta_4 Trade_{t-1} + \delta_5 KOFFI_{t-1} + \delta_6 URB_t + \mu_t \tag{3}$$

Where q is the lag of independent variables, η represents the short-term representation of Variables and λ repents the long-term representation of variables.

$$\Delta ECF_t = \omega_0 + \sum_{i=1}^{m}\omega_1\Delta CO2_{t-i} + \sum_{i=1}^{m}\omega_2\Delta GDP_{t-i} + \sum_{i=1}^{m}\omega_3\Delta EC_{t-i} + \sum_{i=1}^{m}\omega_4\Delta Trade_{t-i} + \sum_{i=1}^{m}\omega_5\Delta KOFFI_{t-i} + \sum_{i=1}^{m}\omega_6\Delta URB_{t-i} + \delta ECT_{t-1} + \mu_t \tag{4}$$

Where, ECT_{t-1} is the error correction term and δ indicates the speed of adjustment. We expect a negative relationship between ECM and the dependent variable.

The following step is to modify Eq. 3 so that it can be used to calculate the asymmetric effects of agricultural production on CO2 emissions. To that end, using the partial sum idea proposed by Shin et al. (2014), Agr is separated into two new time-series variables (positive and negative changes) as follows.

$$Agr_t^+ = \sum_{i=1}^{t}\Delta Agr_t^+ + \sum_{i=1}^{t}\max\left(\Delta Agr_t^+, 0\right) \tag{5}$$

$$Agr_t^- = \sum_{i=1}^{t}\Delta Agr_t^- + \sum_{i=1}^{t}\max\left(\Delta Agr_t^-, 0\right) \tag{6}$$

where the Agr_t^+ indicates an increase in agricultural productivity, while Agr_t^- indicate a decrease in agricultural productivity. After substituting these new variables for the original variable in Eq. 2, our extended model is as follows:

$$CO_{2t} = \eta_0 + \sum_{i=1}^{q}\eta_1(CO_2)_{t-1} + \sum_{i=1}^{q}\eta_4(Agr)_{t-i}^+ + \sum_{i=1}^{q}\eta_4(Agr)_{t-i}^- + \sum_{i=1}^{q}\eta_6(GDP)_{t-i} + \sum_{i=1}^{q}\eta_7(EC)_{t-i} + \sum_{i=1}^{q}\eta_7(Trade)_{t-i} + \sum_{i=1}^{q}\eta_8(GlOB)_{t-i} + \sum_{i=1}^{q}\eta_9(URB)_{t-i} + \lambda_1 CO_{2t} + \lambda_4(Agr)_t^+ + \lambda_4(Agr)_t^- + \lambda_6(GDP)_t + \lambda_7(EC)_t + \lambda_8(Trade)_t + \lambda_9(GlOB)_t + \lambda_{10}(URB)_t + \mu_t \tag{7}$$

TABLE 2 Phillip Perran Unit root test.

	At level		At 1st difference		
	t-Statistic	Prob	t-Statistic	Prob	Decision
CO2	−0.5839	0.8648	−4.2073	0.0016***	I (1)
AGRI	−2.3066	0.1739	−6.4708	0.0000***	I (1)
GDPCN	0.5021	0.9852	−5.8829	0.0000***	I (1)
LEC	−3.3785	0.0165**	−2.2968	0.177	I (0)
TRADE	−3.5872	0.0095***	−7.2016	0.0000***	I (1)
URB	−4.393	0.0009***	−1.477	0.5368	I (0)
GOBE	−2.1542	0.2252	−6.5735	0.0000***	I (1)
GOB	−0.8072	0.8083	−5.2981	0.0001***	I (1)

(*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1% and (no) Not Significant.

TABLE 3 Breusch-Godfrey Serial Correlation LM Test.

Breusch-godfrey serial correlation lm test			
F-statistic	0.4587	Prob. F (2,24)	0.6375
Obs*R-squared	1.7673	Prob. Chi-Square (2)	0.4133

Source: Author own estimations

Shin et al. (2014) label models such as the asymmetric time series ARDL model in Eq. 7, and the partial sum technique results in nonlinearity. For current research Globalization index and Economic Globalization index. So, now the equations are as follows:

$$\begin{aligned} CO_{2t} = \eta_0 + &\sum_{i=1}^{q}\eta_1 (CO_2)_{t-1} + \sum_{i=1}^{q}\eta_4 (Agr)^{+}_{t-i} + \sum_{i=1}^{q}\eta_4 (Agr)^{-}_{t-i} \\ &+ \sum_{i=1}^{q}\eta_6 (GDP)_{t-i} + \sum_{i=1}^{q}\eta_7 (EC)_{t-i} \\ &+ \sum_{i=1}^{q}\eta_7 (Trade)_{t-i} + \sum_{i=1}^{q}\eta_8 (GlOBE)_{t-i} \\ &+ \sum_{i=1}^{q}\eta_9 (URB)_{t-i} + \lambda_1 CO_{2t} + \lambda_4 (Agr)^{+}_{t} + \lambda_4 (Agr)^{-}_{t} \\ &+ \lambda_6 (GDP)_t + \lambda_7 (EC)_t + \lambda_8 (Trade)_t + \lambda_9 (GlOBE)_t \\ &+ \lambda_{10} (URB)_t + \mu_t \end{aligned} \quad (8)$$

Where.

GLOB represent globalization index and GLOBE represents economic globalization in above equation.

Results and discussion

Unit root test

In this study, we assess the tendency of a unit root test over a time series using Fisher-PP tests by Phillips and Perron, (1988) without the structural break. Additionally, the right model is

TABLE 4 Short run Results.

Variable	Model 1	Model 2	Model 3
C	-2.1867	-2.2753	-1.8949
	-0.0016	-0.0072	-0.0082
AGRI_POS(-1)	0.0310	0.0309	0.0283
	-0.0030	-0.0037	-0.0065
AGRI_NEG (-1)	-0.0202	-0.0216	-0.0162
	-0.0237	-0.0621	-0.0843
LEC	0.2900	0.2844	0.3545
	-0.1014	-0.1192	-0.0455
TRADE	-0.0065	-0.0064	-0.0076
	-0.0006	-0.0020	-0.0003
URB	-0.3592	-0.3491	0.0026
	-0.1990	-0.2279	-0.0864
GDPCN	0.0008	0.0008	0.0006
	-0.0031	-0.0038	-0.0064
GOB		-0.0004	
		-0.8470	
GOBE			0.0025
			-0.2370
CointEq (-1)	-0.8380	-0.8426	-0.8072
	0.0000	0.0000	0.0000

Source: Author own estimations

picked if the integration guidelines for the chosen variables are found. The existence of the unit root under the alternative hypothesis is the null hypothesis of stationarity in the PP test. Table 2 displays the outcomes of the Phillips Perron unit root test. The findings of the unit root test show that several variables, such as CO2, AGRI, GDPCN, GOBE, and GOB, have a unit root issue at a level, while LEC, TRADE, and URB are stationary at level I (0). However, all of the series' variables become stationary at I at the first difference (1). The Nonlinear Autoregressive Distributed Lag (NARDL) cointegration model was introduced by Pesaran et al., in 2001 to address the problem. When a variable has stationarity and a combination of I (0) and I (1), the NARDL method can handle it. Even with a tiny sample size, this model is superior and consistently yields accurate findings (Ghatak and Siddiki, 2001). Endogeneity is another crucial problem that arises during estimate. As suggested by Pesaran et al. (2001) the endogeneity problem can be resolved by adding lags and making the model dynamic.

Serial correlation LM test

Information about the data diagnostic testing is provided in Table 3. We do not reject the null hypothesis that there is no serial correlation because the probability value is greater than 0.05 and the table shows that there is no serial connection among the variables.

Table 4 contains the short run results of NARDL model. We have divided our study into three models. The first model is simple nonlinear model in the absence of globalization and economic globalization for detection of asymmetric impact of AGRI on the CO2 emissions. The second model detect the behavior of AGRI with CO2 emissions in the presence of globalization (GOB) while third model is used to determine the impact of AGRI on CO2 emissions in the presence of economic globalization (GOBE). According to the short run results for model one the AGRI_POS shows significantly positive impact on carbon emission as 1 unit increase in the AGRI_POS led to 0.031 unit increase in the CO2 emissions. Whereas AGRI_NEG shows negative and significant effect on CO2 emissions as 1 unit decrease in the AGRI cause 0.020 units decline in the CO2 emissions. Other controlled variables including TRADE and URB possess positive relationship with CO2 emissions, however, URB is statistically insignificant. 1 unit increase in TRADE decreased the CO2 emission by 0.006 units, whereas 1 unit increase in URB cause CO2 emission to decline by 0.359 units. GDPCN and LEC on the other hand positive relationship with CO2 as 1% increase in LEC likely to increase CO2 emissions by 0.290% and 1 unit increase in GDPCN cause CO2 to increase by 0.0008 units.

Results of model two indicates that in the presence of globalization AGRI_POS, LEC and GDPCN shows positive impact on CO2 emissions, LEC is statistically insignificant. As 1 unit increase in AGRI_POS increases CO2 emissions by 0.0390 units, 1% increase in LEC increase CO2 emissions by 0.284% and 1 unit increase in GDPCN likely to increase CO2 by 0.0008 units. Whereas AGRI_NEG, TRADE, URB and GOB shows negative relationship with CO2 emissions. LEC, GOB and URB are statistically insignificant. 1 unit increase in AGRI_NEG likely to decline CO2 by 0.0216 units, 1 unit increase in TRADE decreased CO2 by 0.0064 units and 1 unit increase in GOB resulted in decline of CO2 by 0.0004 units.

According to the results of model two, in the presence of economic globalization, AGRI POS, LEC, URB, GOBE, and GDPCN have a positive impact on CO2 emissions. As 1 unit increase in AGRI POS increases CO2 emissions by 0.0283 units, 1% increase in LEC increases CO2 emissions by 0.354%, one unit increase in URB increases CO2 emissions by 0.0026 units, and one unit increase in GDPCN increases CO2 emissions by 0.0006 units. A unit increase in GOBE is likely to result in a 0.0025 unit increase in CO2. AGRI NEG and TRADE, on the other hand, show a negative relationship with CO2 emissions. 1 unit increase in AGRI_NEG is expected to reduce CO2 by 0.0162 units, while 1 unit increase in TRADE reduced CO2 by 0.0076 units.

According to the ECM results, the ECM coefficient value for each of the three models is (−0.837), (−0.842), and (−0.807), respectively. As can be seen above, the value of ECM in the long run relationship should be negative and substantial in practical outcomes, demonstrating the cointegration of the variables. According to this ECM number, the annual deviation adjustments for models 1, 2, and three are around 83%, 84%, and 80%, respectively. This demonstrates the three models' stability and quickness of correction. In other words, because the ECM coefficient is quite large, the short deviation's adjustment to the long run time route happens very quickly. In any case, the endogenous variables are the elasticities that show the short-run impact on CO2 emissions, and the ECM model is thought to be stable. According to the ECM value, the shocks from the previous year created disequilibrium as compared to the long-run equilibrium in the current year.

NARDL long run results

The environmental consequences of globalization are a hot topic in international trade policy circles. Globalization has both beneficial and harmful environmental consequences. It has the potential to worsen current environmental concerns while also setting the groundwork for their resolution. People in high-income nations are becoming more environmentally conscious, prompting large corporations to adopt environmentally friendly industrial practices. This finally enhances the environmental standards in these countries. Globalization, despite its positive consequences, has the potential to harm the environment. Globalization may harm environmental quality through increasing production scale, energy consumption, international transportation, and uncontrolled depletion of natural resources, particularly in civilizations that use ecologically unfriendly technologies. So, in current research we conducted a in depth study how globalization and economic globalization affect environment *via* agricultural production. We developed three model. In model there is not any role of globalization for the sake of comparison we included globalization and economic globalization in model two and three respectively.

This study used three models to determine the effect of agricultural production on CO2 emissions along with other controlled variables including GDPCN, LEC, TRADE and URB. First model provided the impact of AGRI_POS and AGRI_NEG in the absence of both globalization and economic globalization. Second model includes the impact of agricultural production on CO2 in presence of globalization while third model contains economic globalization. The long run results depicted in Table 5 concluded the asymmetric

TABLE 5 Long-run results.

Variable	Model 1	Model 2	Model 3
AGRI_POS	0.0370	0.0367	0.0351
	−0.0009	−0.0013	−0.0025
AGRI_NEG	−0.0241	−0.0256	−0.0201
	−0.0143	−0.0426	−0.0645
GDPCN	0.0012	0.0012	0.0011
	0.0000	0.0000	0.0000
LEC	0.8562	0.8733	0.7446
	0.0000	−0.0001	−0.0003
TRADE	−0.0128	−0.0127	−0.0132
	0.0000	0.0000	0.0000
URB	−0.0316	−0.0300	−0.0282
	−0.2913	−0.3362	−0.3579
GOB		−0.0005	
		−0.8463	
GOBE			0.0031
			−0.2448

Source: Author own estimations.

behavior of agricultural production with CO2. According to the results AGRI_POS has positive and significant impact on CO2 while AGRI_NEG has negative impact in all three models. As 1 unit increase in AGRI_POS increases the CO2 emission by 0.0370 units, 0.0367 units and 0.0351 units for model 1, two and three respectively. According to Lynch et al. (2021) agriculture is the main contributor to the global warming. While livestock and changes in land use account for a significant portion of emissions, crop production also makes up around 14% Hillier et al. (2009).

This positive trend demonstrates that Pakistan's CO2 emissions climb as agricultural production increases. Our findings back up Holly's (2015) claims that nitrous oxide and methane emissions from soil management and livestock practices are a significant contributor to CO2 emissions in agriculture. Additionally, the agriculture industry emits CO2 since it employs non-renewable energy sources like fuel and oil for irrigation. According to Reynolds and Wenzlau (2012), agriculture requires a lot of fossil fuel to pump water, irrigate crops, and make nitrogen-rich fertilizer, which accounts for 14%–30% of all greenhouse gas emissions. According to the IAEA report, agricultural operations account for 30% of all greenhouse gas emissions, primarily as a result of the use of chemical fertilizers, pesticides, and animal manure. Due to the rising global population's increased demand for food, the increased demand for dairy and meat products, and the intensification of agricultural processes, this rate is only going to continue to increase. Last but not least, in order to protect their crops, farmers utilize nitrogen-rich fertilizers, which also increase CO2 emissions. One of Pakistan's key economic sectors, agriculture contributes 18.9% of the country's GDP in 2021 (Pakistan Bureau of Statistics).

According to results of Sui and Lv (2021) the increase in agriculture inputs in crop production, leading to agricultural CO2 emissions increasing with a growth rate of 36.2%. Both conventional and contemporary farming techniques are used. Modern farming techniques including organic farming, solar tube well irrigation, and tunnel farming are widely used in irrigated areas where vegetables and fruits are grown. It has been seen that large farms use these modern agricultural techniques to boost production, cut labor requirements, and minimize greenhouse gas emissions (Panhwar et al., 2019). However, the bulk of Pakistan's farmland is owned by small farmers who continue to practice conventional farming practices that contribute to greenhouse gas emissions. Xu and Lin (2019) and Li et al. (2020) on the other hand also found that the modern agricultural activities using nonrenewable resources are now becoming the major contributor in greenhouse gas emissions due to their high input material and energy consumption that as a result discharge high level of pollutants. In addition to utilising more and heavier quantities of pesticides, chemicals and fertilizers are also significantly contributing to the rise in CO2 emissions (Onder et al., 2011). Our findings are also supported by Gokmenoglu and Taspinar (2018); Qiao et al. (2019).

According to long-term data, there is a negative correlation between AGRI_NEG and CO2 emissions, which means that for each unit increase in agricultural production in models 1, 2, and 3, CO2 emissions will reduce by 0.0241, 0.0256, and 0.0201 units, respectively. Because more fossil fuel energy sources, fertilizers, and pesticides are used in agriculture, as a result there is a negative impact on CO2 emissions because these factors have been linked to environmental degradation. The productivity of the agricultural sector also falls because of the economic structural shift from agriculture to the industrial and services sectors, which also results in a reduction in CO2 emissions from agricultural production. In Pakistan, it is especially crucial to consider potential solutions to lower emissions from the livestock production. The use of climate-smart agricultural methods also lowers CO2 emissions from agriculture Imran et al. (2018). Improved animal feed and feeding techniques that lower the amount of methane and nitrous oxide produced during digestion and the decomposition of manure, improved breeding, modified manure storage and management practices, increase productivity and create carbon sinks are some technologies and practices that can increase the efficiency of livestock production while reducing emissions (Shahzad and Abdulai, 2021).

Our research showed that GDP and CO_2 emissions have a long-term and short-term positive relationship. Our research indicates that a 1 unit increase in GDPCN will probably result in CO_2 emissions rising by 0.0012, 0.0012, and 0.0011 units in models 1, 2, and three respectively. Although this scenario appears promising from a macroeconomic standpoint because GDP growth is associated with the creation of jobs and greater living standards, economies must pay the price in terms of environmental quality decline. All of these studies demonstrate that GDP has a favorable impact on CO_2 emissions levels in various economies. For example Mitić et al. (2017); Riti et al. (2017); Caporale et al. (2019); Zhang and Zhang (2020). According to Brock and Taylor, (2010), three key factors, including the scale of production, the composition of the means of production, and the use of technology for production, have a significant impact on the relationship between economic growth and environmental quality. Due to the economic activity represented by a sizable number of firms that produce CO_2 emissions, it is typical for emerging countries' economies to experience rising CO_2 emissions as their economies grow on average Khan et al. (2020). As Pakistan is not a very large economy and having low GDP, its effects on CO_2 emissions are very minor. These minor adverse effects may be due to the old equipment and technology used in the production of goods and services.

Our findings reveal the positive relationship of energy consumption with CO_2 emissions. Our study results are in line with that of Hu et al. (2021). According to results 1% increase in LEC contributes 0.8562%, 0.8733% and 0.7446% increase in the CO_2 emissions in model 1, two and three respectively. This substantial rise in CO_2 emissions is primarily due to Pakistan's primary energy supply mix. According to National Electric Power Regulatory Authority's (NEPRA) 2020 yearly report Pakistan's total installed power generation capacity, which is 38,700 MW, 57 percent of the country's energy comes from thermal sources (fossil fuels), 31% from hydroelectricity, 4% from renewable sources (wind, Sun, and bagasse), and 8% from nuclear power. In Pakistan's overall energy mix, a shift from non-renewable to renewable energy sources could help cut carbon dioxide emissions. The increase in energy use in the industrial, transportation, and agricultural sectors is another factor contributing to the rise in CO_2 emissions. Industry, transportation, and agriculture account for 35% (13.94 MTOE), 32% (12.74 MTOE), and 25% (9.96 MTOE) of total energy consumption, respectively. The Pakistani government has not done much to address difficulties with renewable energy sources and environmental change despite this dire position (Raheem et al., 2016; Wen et al., 2021).

Trade shows a significant negative relation with CO_2 emissions in each of three model. Long run NARDL results reveals that the trade reduces the emissions of carbon in both absence and presence of globalization and economic globalization. 1 unit increase in trade resulted in the reduction of CO_2 by 0.0128, 0.0127 and 0.0132 units in model 1, two and three respectively. This pattern demonstrates how environmental protection was improved and cutting-edge technology was implemented together with the rapid economic development brought on by greater global trade. The majority of nations are aware of how important it is to lower carbon emissions. As a result, improvements in pollution prevention and control were made, and carbon emission reductions were made to some extent Gao et al. (2021). These variations are connected to certain phases, dynamics, and continuity aspects of how international trade affects carbon emissions. Sun et al. (2019), Abbas et al. (2022) also considered green innovation, and energy efficiency responsible for the reduction of CO_2 emission due to trade. Wang et al. (2018), Ali et al. (2022) discovered that raising the rate of economic growth and boosting international commerce are helpful for improving environmental effects. Our results are also supported by the findings of (Misaki et al., 2018; Li and Wang, 2019).

The long run examined results of NARDL shows positive but insignificant impact of economic globalization in case of Pakistan. The results indicate that 1 unit increase in economic globalization will increase CO_2 emissions by 0.0031 units. The results of economic globalization show that as investment between Pakistan and other nations increase, developed nations are encouraged to invest there. At the same time, developed nations are shifting their pollution-producing industries to Pakistan, which accelerates environmental degradation (Khan et al., 2019). The results of the economic globalization study are consistent with earlier ones like Danish and Wang, (2018) and Ahmed et al. (2015) investigated how economic globalization has affected natural resources. The results under close examination revealed that economic globalization is destroying the natural resources that lead to environmental deterioration.

Globalizations seem to have a little but detrimental impact on CO_2 emissions. As 1 unit more GOB will probably result in 0.0005 unit decreased CO_2 emissions. The transfer of advanced technology and knowledge from other nations is too responsible for this negative influence of globalization, which will not only reduce the demand for energy produced by conventional sources but also minimize the energy demand. The establishment of new businesses equipped with cutting-edge and creative technologies enhances production while consuming less energy Shahbaz et al. (2016a). The transfer of technology from developed to developing countries, aids in the promotion of the division of labor and raises the overall labor productivity of various countries according to Shahbaz et al. (2017). This shows that globalization declines CO_2 emissions *via* income effect, scale effect and technique effect. Our study also linked with the results of Antweiler et al. (2001) and Liddle (2001).

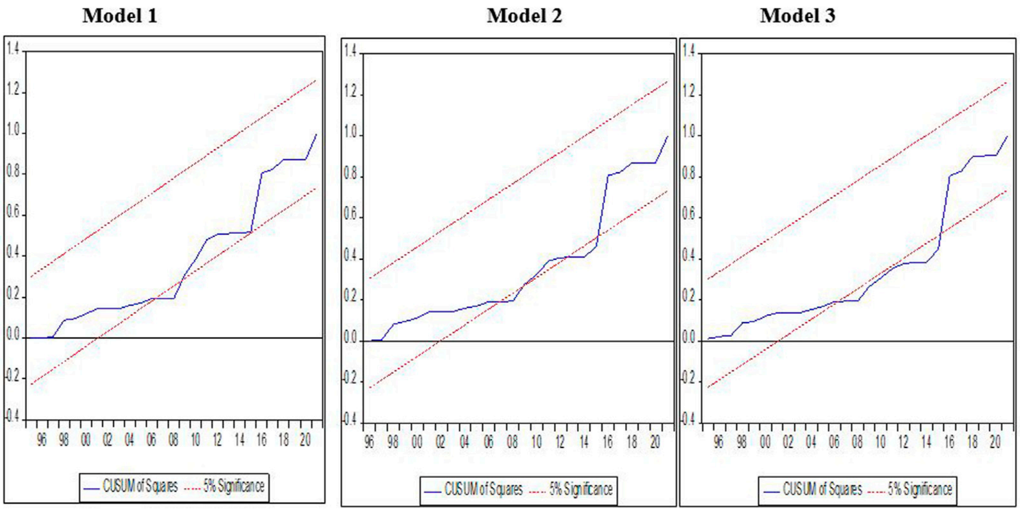


FIGURE 4
CUSUMSQ.

TABLE 6 Bound test results.

F-bound test

Value	Signif. (%)	I (0)	I (1)
5.26974	10	1.92	2.89
5.416037	5	2.17	3.21
4.993186	2.50	2.43	3.51
	1	2.73	3.9

Bound test

The results of the bound test of the ARDL model are shown in Table 6. In order to avoid the computed F-stat becoming invalid in the model suggested by Pesaran et al. (2001) the above bound test assumes that there are only variables with the orders I (0) or I (1) and none with I (2). The table lists upper and lower limits for various confidence intervals. For model selection, our models rely on a 95% confidence interval. Indicating a long-term cointegration between the variables in both models, the F-stat value of our bound result for our model is 5.269, larger than the upper bound value of 3.21.

Structural stability test

USUM and CUSUM of the square test, first introduced by Brown et al. (1975), are now commonly utilized. This test is performed using a visualization of the sum of recursive residuals. The plotting charts for this exam show two straight red lines. A single blue line is inserted between these two lines to reflect the proportion of the important link. Because we rejected all of the expected variables, our data is nonlinear if blue lines overlap red lines. However, we do not dismiss projected variables that indicate that our data is linear if the plot remains contained inside two straight lines. However, the cumulative test can also show whether the coefficient of regression is changing unexpectedly. The CUSUM test detected whether the coefficient of the variables changes consistently. Figure 4 depicts CUSUM Square graphs for all three models. According to the CUSUMSQ testing, the blue line for all three models surpassed a little more than two redlines, but the models are still dependable.

Conclusion

Concern grows as the risk of climate change caused by carbon dioxide emissions persists. Identifying the factors that cause emissions and devising mitigation measures, particularly within the framework of sectors and sub-sectors, is critical in this context. Agriculture, like many other industries, emits CO2 and may be affected by climate change. As a result, the current study employed NARDL to analyze data from 1971 to 2021 to estimate the uneven impact of agricultural output on CO2 emissions under the globalization scenario. The findings demonstrated that agricultural production, energy consumption, globalization, and CO2 emissions are linked in both the short and long run. Indeed, as evidenced by the current study's findings, agricultural output was effective in increasing emission increases in the face of globalization. Consequently, our findings will contribute significantly to the process of developing and refining policies targeted at reducing agricultural emissions and ensuring agricultural sustainability.

In view of the findings in our study agriculture production, GDPCN, LEC, are significant contributor of carbon emissions however trade has negative impact on CO2 emission. However, impact of globalization and economic globalization found to be insignificant with carbon emissions.

Policy recommendations

Following are the recommendations which helps reduce the carbon emissions in Pakistan:

1.Since increased agricultural production greatly increases carbon emissions, it is important to take steps to increase agricultural productivity without compromising food security. Prior to creating rules to restrict pesticides and chemical fertilizers, the government ought to set up a mechanism for evaluating the agricultural green economy. The environment is contaminated, agricultural carbon emissions rise, and soil health is harmed by the overuse of chemical and agricultural fertilizers. Therefore, according to the features of the local agricultural growth, local governments should create regulations on the use of pesticides, chemical fertilizers, and other elements. Second, the relevant authorities need to adopt policies to encourage the development of modern agricultural facilities, the support role of research and technology, high-quality agricultural development, and environmentally friendly agricultural growth. Third, adapt agricultural development to regional conditions. The backbone of the national economy is agriculture. Regional factor endowments are more of a constraint on agricultural productivity in the narrow sense. To close the regional gap in the effects of agricultural production efficiency and agricultural carbon emission intensity, strategies must be developed in accordance with local realities.

2Energy consumption has significantly positive impact on carbon emission due to large consumption of fossils fuels and other nonrenewable resources in the vehicles and electricity production. The government should therefore focus on the use of renewable energy production resources like wind, solar and hydel *etc.* The use of nonrenewable will cut down the cost of production and significantly reduces the carbon emissions.

3.Based on our research, trade contributes to a decrease in carbon emissions. Pakistan relies heavily on imported goods and services, which results in lower domestic production and a corresponding drop in carbon emissions. Therefore, businesses in Pakistani industries must be encouraged to import eco-friendly (green) technology by imposing the lowest possible tariffs. Similar incentives must be offered to promote R&D in the industrial sector so that businesses can improve both their production and energy consumption efficiency. In order to encourage industries to adopt the green idea, the government must also provide special incentives in the form of tax relief or exemption. This will allow exporters to increase export variety and assist Pakistan in reducing environmental degradation.

4.In the last but not least, government should promote organic farming so that CO2 emissons can be reduced. Furthermore, technological innovation in different agricultural practices can reduce CO2 emissions by promoting energy efficiency.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: https://databank.worldbank.org/source/world-development-indicatorsandlt.

Author contributions

NK: Conceptualization, data collection, and writeup. AF: analysis and review. KA: methodology and review. JK † US: data curation and proofread.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Abbas, S., Gui, P., Chen, A., and Ali, N. (2022). The effect of renewable energy development, market regulation, and environmental innovation on CO2 emissions in BRICS countries. *Environ. Sci. Pollut. Res.*, 1–19.

Ahmed, K., Shahbaz, M., Qasim, A., and Long, W. (2015). The linkages between deforestation, energy, and growth for environmental degradation in Pakistan. *Ecol. Indic.* 49, 95–103. doi:10.1016/j.ecolind.2014.09.040

Al-Mulali, U., Solarin, S. A., Sheau-Ting, L., and Ozturk, I. (2016). Does moving towards renewable energy cause water and land inefficiency? An empirical investigation. *Energy Policy* 93, 303–314. doi:10.1016/j.enpol.2016.03.023

Ali, N., Phoungthong, K., Techato, K., Ali, W., Abbas, S., Dhanraj, J. A., et al. (2022). FDI, Green innovation and environmental quality nexus: New insights from BRICS economies. *Sustainability* 14 (4), 2181. doi:10.3390/su14042181

Alkan, A., and Binatli, A. O. (2021). Is production or consumption the determiner? Sources of Turkey's CO2 emissions between 1990-2015 and policy implications. *Hacet. Üniversitesi İktisadi ve İdari Bilim. Fakültesi Derg.* 39 (3), 359–378. doi:10.17065/huniibf.823845

Antweiler, W., Copeland, B. R., and Taylor, M. S. (2001). Is free trade good for the environment? *Am. Econ. Rev.* 91 (4), 877–908. doi:10.1257/aer.91.4.877

Appiah, K., Du, J., and Poku, J. (2018). Causal relationship between agricultural production and carbon dioxide emissions in selected emerging economies. *Environ. Sci. Pollut. Res.* 25 (25), 24764–24777. doi:10.1007/s11356-018-2523-z1007/s11356-019-07486-9

Asongu, S. A., and Odhiambo, N. M. (2019). Basic formal education quality, information technology, and inclusive human development in sub-Saharan Africa. *Sustain. Dev.* 27 (3), 419–428. doi:10.1002/sd.1914

Asumadu-Sarkodie, S., and Owusu, P. A. (2017). The causal nexus between carbon dioxide emissions and agricultural ecosystem-an econometric approach. *Environ. Sci. Pollut. Res.* 24 (2), 1608–1618.

Aswani, S., Lemahieu, A., and Sauer, W. H. (2018). Global trends of local ecological knowledge and future implications. *PloS one* 13 (4), e0195440. doi:10.1371/journal.pone.0195440

Baek, J. (2016). Do nuclear and renewable energy improve the environment? Empirical evidence from the United States. *Ecol. Indic.* 66, 352–356. doi:10.1016/j.ecolind.2016.01.059

Brock, W. A., and Taylor, M. S. (2010). *World bank*. Geneva: World development indicators.

Brown, R. L., Durbin, J., and Evans, J. M. (1975). Techniques for testing the constancy of regression relationships over time. *J. R. Stat. Soc. Ser. B Methodol.* 37 (2), 149–163. doi:10.1111/j.2517-6161.1975.tb01532.x

Caporale, G. M., Claudio-Quiroga, G., and Gil-Alana, L. A. (2019). *CO2 emissions and GDP: Evidence from China*.

Carroccio, A., Crescimanno, M., Galati, A., and Tulone, A. (2016). The land grabbing in the international scenario: The role of the EU in land grabbing. *Agric. Food Econ.* 4 (1), 12–19. doi:10.1186/s40100-016-0056-7

Chen, C., Woods, M., Chen, J., Liu, Y., and Gao, J. (2019). Globalization, state intervention, local action and rural locality reconstitution-a case study from rural China. *Habitat Int.* 93, 102052. doi:10.1016/j.habitatint.2019.102052

Constantin, M., Rădulescu, I. D., Andrei, J. V., Chivu, L., Erokhin, V., and Gao, T. (2021). A perspective on agricultural labor productivity and greenhouse gas emissions in context of the Common Agricultural Policy exigencies. *Ekon. Poljopr.* 68 (1), 53–67. doi:10.5937/ekopolj2101053c

Danish, Z., and Wang, Z. (2018). Dynamic relationship between tourism, economic growth, and environmental quality. *J. Sustain. Tour* 26 (11), 1928–1943.

Gao, J. L., Gao, F. F., and Zhang, M. W. (2021). International trade as a double-edged sword: From the perspective of carbon emissions. *Front. Energy Res.* 688.

Ghatak, S., and Siddiki, J. (2001). The use of the ARDL approach in estimating virtual exchange rates in India. *J. Appl. Stat.* 28 (5), 573–583. doi:10.1080/02664760120047906

Gokmenoglu, K. K., and Taspinar, N. (2018). Testing the agriculture induced EKC hypothesis: The case of Pakistan. *Environ. Sci. Pollut. Res.* 25 (23), 22829–22841. doi:10.1007/s11356-018-2330-6

GOP (2017). *Agricultural Statistics of Pakistan, 2016/17*, 2017. Islamabad: Ministry of Food, Agriculture and Livestock, Government of Pakistan.

Haseeb, A., Xia, E., Baloch, M. A., and Abbas, K. (2018). Financial development, globalization, and CO2 emission in the presence of EKC: Evidence from BRICS countries. *Environ. Sci. Pollut. Res.* 25 (31), 31283–31296. doi:10.1007/s11356-018-3034-7

Hillier, J., Hawes, C., Squire, G., Hilton, A., Wale, S., and Smith, P. (2009). The carbon footprints of food crop production. *Int. J. Agric. Sustain.* 7 (2), 107–118. doi:10.3763/ijas.2009.0419

Holly, R. (2015). *The complicated relationship between agriculture and climate change*.

Hu, X., Ali, N., Malik, M., Hussain, J., Fengyi, J., and Nilofar, M. (2021). Impact of economic openness and innovations on the environment: A new look into ASEAN countries. *Pol. J. Environ. Stud.* 30, 3601–3613.

IEA. (2016). International energy agency. Available at https://www.eia.gov/outlooks/ieo/pdf/0484(2016).pdf.

Imran, M. A., Ali, A., Ashfaq, M., Hassan, S., Culas, R., and Ma, C. (2018). Impact of Climate Smart Agriculture (CSA) practices on cotton production and livelihood of farmers in Punjab, Pakistan. *Sustainability* 10 (6), 2101. doi:10.3390/su10062101

IPCC (2015). *Climate change synthesis report. Contribution of working groups I, II and III to the fifth assessment report of the intergovernmental panel on climate change*.

IPCC (2014). *Climate change: Mitigation of climate change*. Cambridge, UK: Cambridge University Press.

Iram, U., and Fatima, A. (2008). International trade, foreign direct investment, and the phenomenon of child labor: The case of Pakistan. *Int. J. Soc. Econ.* 35 (11), 809–822. doi:10.1108/03068290810905432

Khan, A. N., Ghauri, B. M., Jilani, R., and Rahman, S. (2011). "Climate change: Emissions and sinks of greenhouse gases in Pakistan," in Proceedings of the Symposium on Changing Environmental Pattern and its impact with Special Focus on Pakistan.

Khan, M. A., Tahir, A., Khurshid, N., Husnain, M. I. U., Ahmed, M., and Boughanmi, H. (2020b). Economic effects of climate change-induced loss of agricultural production by 2050: A case study of Pakistan. *Sustainability* 12 (3), 1216. doi:10.3390/su12031216

Khan, M. K., Khan, M. I., and Rehan, M. (2020a). The relationship between energy consumption, economic growth and carbon dioxide emissions in Pakistan. *Financ. Innov.* 6 (1), 1–13. doi:10.1186/s40854-019-0162-0019-0162-0

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

Lahiri Dutt, K. (2004). Informality in mineral resource management in Asia: Raising questions relating to community economies and sustainable development. *Nat. Resour. Forum* 28 (2), 123–132.

Lanfranchi, M., Giannetto, C., Rotondo, F., Ivanova, M., and Dimitrova, V. (2019). Economic and social impacts of price volatility in the markets of agricultural products. *Bulg. J. Agric. Sci.* 25, 1063–1068.

Leal, P. H., and Marques, A. C. (2020). Rediscovering the EKC hypothesis for the 20 highest CO2 emitters among OECD countries by level of globalization. *Int. Econ.* 164, 36–47. doi:10.1016/j.inteco.2020.07.001

Li, N., Wei, C., Zhang, H., Cai, C., Song, M., and Miao, J. (2020). Drivers of the national and regional crop production-derived greenhouse gas emissions in China. *J. Clean. Prod.* 257, 120503. doi:10.1016/j.jclepro.2020.120503

Li, S., and Wang, S. (2019). Examining the effects of socioeconomic development on China's carbon productivity: A panel data analysis. *Sci. Total Environ.* 659, 681–690. doi:10.1016/j.scitotenv.2018.12.409

Liddle, B. (2001). Free trade and the environment-development system. *Ecol. Econ.* 39, 21–36. doi:10.1016/s0921-8009(01)00215-4

Liu, X., Zhang, S., and Bae, J. (2017). The impact of renewable energy and agriculture on carbon dioxide emissions: Investigating the environmental kuznets curve in four selected ASEAN countries. *J. Clean. Prod.* 164, 1239–1247. doi:10.1016/j.jclepro.2017.07.086

Lynch, J., Cain, M., Frame, D., and Pierrehumbert, R. (2021). Agriculture's contribution to climate change and role in mitigation is distinct from predominantly fossil CO2-emitting sectors. *Front. Sustain. Food Syst.* 4, 518039. doi:10.3389/fsufs.2020.518039

Majeed, M. T., and Luni, T. (2019). Renewable energy, water, and environmental degradation: A global panel data approach. *Pak. J. Commer. Soc. Sci. (PJCSS)* 13 (3), 749–778.

Mariyakhan, K., Mohamued, E. A., Asif Khan, M., Popp, J., and Oláh, J. (2020). Does the level of absorptive capacity matter for carbon intensity? Evidence from the USA and China. *Energies* 13 (2), 407. doi:10.3390/en13020407

Misaki, E., Apiola, M., Gaiani, S., and Tedre, M. (2018). Challenges facing sub-saharan small-scale farmers in accessing farming information through mobile phones: A systematic literature review. *E. J. Info. Sys. Dev. Ctries.* 84 (4), e12034. doi:10.1002/isd2.12034

Mitić, P., Munitlak Ivanović, O., and Zdravković, A. (2017). A cointegration analysis of real GDP and CO2 emissions in transitional countries. *Sustainability* 9 (4), 568. doi:10.3390/su9040568

Muhammad, S., Long, X., Salman, M., and Dauda, L. (2020). Effect of urbanization and international trade on CO2 emissions across 65 belt and road initiative countries. *Energy* 196, 117102. doi:10.1016/j.energy.2020.117102

Onder, M., Ceyhan, E., and Kahraman, A. (2011). "Effects of agricultural practices on environment," in International Conference on Biology, Environment and Chemistry, Singapore, 28–30.

Panhwar, Q. A., Ali, A., Naher, U. A., and Memon, M. Y. (2019). "Fertilizer management strategies for enhancing nutrient use efficiency and sustainable wheat production," in *Organic farming* (Woodhead Publishing), 17–39.

Paramati, S. R., Shahbaz, M., and Alam, S. (2017). Does tourism degrade environmental quality? A comparative study of eastern and western European union. *Transp. Res. Part D Transp. Environ.* 50, 1–13. doi:10.1016/j.trd.2016.10.034

Perrier, Q., Guivarch, C., and Boucher, O. (2019). Diversity of greenhouse gas emission drivers across European countries since the 2008 crisis. *Clim. Policy* 19 (9), 1067–1087. doi:10.1080/14693062.2019.1625744

Pesaran, M. H., Shin, Y., and Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *J. Appl. Econ. Chichester. Engl.* 16, 289–326. doi:10.1002/jae.616

Peyraud, J. L., Taboada, M., and Delaby, L. (2014). Integrated crop and livestock systems in western Europe and south America: A review. *Eur. J. Agron.* 57, 31–42. doi:10.1016/j.eja.2014.02.005

Phillips, P. C., and Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika* 75 (2), 335–346.

Popp, J., Oláh, J., Farkas Fekete, M., Lakner, Z., and Máté, D. (2018). The relationship between prices of various metals, oil and scarcity. *Energies* 11 (9), 2392. doi:10.3390/en11092392

Qiao, H., Zheng, F., Jiang, H., and Dong, K. (2019). The greenhouse effect of the agriculture-economic growth-renewable energy nexus: Evidence from G20 countries. *Sci. Total Environ.* 671, 722–731. doi:10.1016/j.scitotenv.2019.03.336

Raheem, A. R., Herawati, E. Y., Nursyam, H., and Hariati, A. M. (2016). Combination of Vermicompost Fertilizer, Carbon, Nitrogen and Phosphorus on Cell Characteristics, Growth and Quality of Agar Seaweed Gracilaria verrucosa. *Nat. Environ. Pollut. Technol.* 15 (4), .

Reynolds, L., and Wenzlau, S. (2012). *Climate-friendly agriculture and renewable energy: Working hand-in-hand toward climate mitigation*.

Riti, J. S., Song, D., Shu, Y., and Kamah, M. (2017). Decoupling CO2 emission and economic growth in China: Is there consistency in estimation results in analyzing environmental kuznets curve? *J. Clean. Prod.* 166, 1448–1461. doi:10.1016/j.jclepro.2017.08.117

Rodrik, D., Subramanian, A., and Trebbi, F. (2004). Institutions rule: The primacy of institutions over geography and integration in economic development. *J. Econ. growth* 9 (2), 131–165. doi:10.1023/B:JOEG.0000031425.72248.85

Sarkodie, S. A., and Strezov, V. (2018). Assessment of contribution of Australia's energy production to CO2 emissions and environmental degradation using statistical dynamic approach. *Sci. Total Environ.* 639, 888–899. doi:10.1016/j.scitotenv.2018.05.204

Sarkodie, S. A., Strezov, V., Weldekidan, H., Asamoah, E. F., Owusu, P. A., and Doyi, I. N. Y. (2019). Environmental sustainability assessment using dynamic autoregressive-distributed lag simulations—Nexus between greenhouse gas emissions, biomass energy, food and economic growth. *Sci. total Environ.* 668, 318–332. doi:10.1016/j.scitotenv.2019.02.432

Saud, S., Baloch, M. A., and Lodhi, R. N. (2018). The nexus between energy consumption and financial development: Estimating the role of globalization in next-11 countries. *Environ. Sci. Pollut. Res.* 25 (19), 18651–18661. doi:10.1007/s11356-018-2069-0

Shahbaz, M., Mallick, H., Mahalik, M. K., and Sadorsky, P. (2016a). The role of globalization on the recent evolution of energy demand in India: Implications for sustainable development. *Energy Econ.* 55, 52–68. doi:10.1016/j.eneco.2016.01.013

Shahbaz, M., Khan, S., Ali, A., and Bhattacharya, M. (2017). The impact of globalization on CO2 emissions in China. *Singap. Econ. Rev.* 62 (04), 929–957. doi:10.1142/s0217590817400331

Shahbaz, M., Mahalik, M. K., Shah, S. H., and Sato, J. R. (2016b). Time-varying analysis of CO2 emissions, energy consumption, and economic growth nexus: Statistical experience in next 11 countries. *Energy Policy* 98, 33–48. doi:10.1016/j.enpol.2016.08.011

Shahzad, M. F., and Abdulai, A. (2021). The heterogeneous effects of adoption of climate-smart agriculture on household welfare in Pakistan. *Appl. Econ.* 53 (9), 1013–1038. doi:10.1080/00036846.2020.1820445

Shin, Y., Yu, B., and Greenwood-Nimmo, M. (2014). *Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework*. New York, NY: In Festschrift in honor of Peter Schmidt (pp. 281-314). Springer.

Sokil, O., Zhuk, Z., and Vasa, L. (2018). Integral assessment of the sustainable development of agriculture in Ukraine. *Econ. annals-XXI* 170 (170), 15–21. doi:10.21003/ea.V170-03

Sui, J., and Lv, W. (2021). Crop production and agricultural carbon emissions: Relationship diagnosis and decomposition analysis. *Int. J. Environ. Res. Public Health* 18 (15), 8219. doi:10.3390/ijerph18158219

Sun, H., Edziah, B. K., Sun, C., and Kporsu, A. K. (2019). Institutional quality, green innovation and energy efficiency. *Energy Policy* 135, 111002. doi:10.1016/j.enpol.2019.111002

Swisher, M. E., Ruiz-Menjivar, J., and Koenig, R. (2018). Value chains in renewable and sustainable food systems. *Renew. Agric. Food Syst.* 33 (1), 1–5. doi:10.1017/s1742170517000667S174217051700067

Trinh, T. A., Feeny, S., and Posso, A. (2021). "The impact of natural disasters and climate change on agriculture: Findings from Vietnam," in *Economic effects of natural disasters* (Academic Press), 261–280.

Van der Werf, H. M. (1996). Assessing the impact of pesticides on the environment. *Agric. Ecosyst. Environ.* 60 (2-3), 81–96. doi:10.1016/s0167-8809(96)01096-1

Varsava, J. A. (2003). Creative destruction: How globalization is changing the world's cultures. Available at https://www.jstor.org/stable/40536953.

Wang, P., Du, G., and Jiang, X. (2018). Study on the structural decomposition of implied carbon emissions in China's export trade — based on the comparative analysis of industrial trade carbon emissions data between China and its trading partners [J]. *Price Theor. Pract.*

Wen, J., Ali, W., Hussain, J., Khan, N. A., Hussain, H., Ali, N., et al. (2021). Dynamics between green innovation and environmental quality: New insights into south asian economies. *Economia Politica*, 1–23.

World Bank (2007). *Growth and CO2 emissions: How do different countries fare*. Washington, DC, USA: Environment Department.

World Meteorological Organization (2017). *WMO statement on the state of the global climate in 2016*.

Xu, B., and Lin, B. (2019). Can expanding natural gas consumption reduce China's CO2 emissions? *Energy Econ.* 81, 393–407. doi:10.1016/j.eneco.2019.04.012

Yilanci, V., and Pata, U. K. (2020). Convergence of per capita ecological footprint among the ASEAN-5 countries: Evidence from a non-linear panel unit root test. *Ecol. Indic.* 113, 106178. doi:10.1016/j.ecolind.2020.106178

Zhang, J., and Zhang, Y. (2020). Tourism, economic growth, energy consumption, and CO2 emissions in China. *Tour. Econ.* 1354816620918458, 1060–1080. doi:10.1177/1354816620918458