



Asymmetric effects of premature deagriculturalization on economic growth and CO₂ emissions: fresh evidence from Pakistan

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Abstract

This paper examines the relationship between deagriculturalization, economic growth, and CO₂ emissions in Pakistan from the period 1975 to 2018 by employing a nonlinear autoregressive distributed lag (NARDL) model and Granger causality approach. The asymmetric ARDL findings show that there is a significant negative relationship between agriculturalization and economic growth, while deagriculturalization does not induce economic growth in the long run in Pakistan. Moreover, agriculturalization and deagriculturalization have a negative significant effect on Pakistan's carbon emissions in the long run. This study concludes that the asymmetric results deviate from symmetric results in Pakistan. The asymmetric causality test shows unidirectional asymmetric causality running from agriculturalization, deagriculturalization, and CO₂ emissions. Moreover, agriculturalization and deagriculturalization do not Granger cause economic growth in Pakistan. Based on the results, the study stressed to formulate such policies which support economic growth and lower carbon emissions through reforming agriculture sector practices. These outcomes are very useful for Pakistan to formulate relevant policies.

Keywords Deagriculturalization · Economic growth · CO₂ emissions · NARDL · Pakistan

Introduction

Agriculture is considered a panacea for sustainable economic growth and development across the globe. The physiocracy school of thought has validated this claim (Higgs 1897). The premise of the ideology that agriculture is the key source of economic growth in comparison to other schools of thought such as mercantilism is supported in the literature by Victor

Bekun and Akadiri (2019) and Sertoglu et al. (2017). However, the path to how this translates into long-term economic gain has been an issue of considerable interest and debate among agricultural economists and policymakers.

Generally, empirical studies have concluded that the agriculture sector contributes to economic growth by increasing agricultural exports (Ram 1987; Balassa 1978; Voivodas 1973). On the contrary, some studies do not confirm the positive effect of the agriculture sector on economic growth. For example, Tiffin and Irz (2006) showed in a sample of 85 countries from 1960 to 1971 that agricultural output stimulates economic growth in developing economies but not in developed economies. Shaikh (2011) concluded agricultural sector did not contribute to output growth because of inefficient export policies. Faridi (2012) showed that agricultural exports did not significantly contribute to the growth of Pakistan over the period 1972–2008. The empirical studies have used linear methods of analysis and ignored the role of agriculturalization in explaining economic performance.

Moreover, over time, the demand for agricultural commodities has been increased. The increasing demand for agricultural products has increased the demand for energy use. In the case of developing countries, energy use largely depends on nonrenewable energy sources (Majeed and Luni 2019), which

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increase greenhouse gas (GHG) emissions in the atmosphere. Thus, agricultural expansion has environmental repercussions (Gokmenoglu and Taspinar 2018). According to FAO (2016), the agricultural sector is contributing to global warming and climate change by producing almost one third of global GHG anthropogenic emissions. Environmental implications of agriculture are particularly intensified after the global food crisis over the period 2006–2008.

Agriculture is the second largest contributor to global GHG emissions. Deforestation to expand agriculture activities create environmental problems. The forest woods are used for cooking, which increases CO₂ emissions. Moreover, agricultural activities comprise bush and biomass burning (Ramachandra et al. 2015). In contrast, FAO (2016) suggested that the agriculture sector has the potential to lower GHG emissions by 20 to 60% in 2030. The favorable role of agriculture can be made through reducing deforestation, innovating more hybrid varieties of forest plants, fertilizer applications to alleviate fossil fuels, and adoption of clean sources of energy such as solar and wind energy (Reynolds et al. 2015; Mohamad et al. 2016; Liu et al. 2017). Pakistan is an agrarian economy with a considerable amount of agricultural soil and agricultural export capacity.

The agricultural sector in Pakistan contributes 23% of GDP and absorbs 37% of the labor force, suggesting that the economy is largely dependent on agriculture. The major crop of Pakistan is rice; it contributes 6% of pollution emissions, and 2.1% of emissions come from agricultural soil. These pollution emissions come from water mismanagement, inefficient fertilizer applications, and various agricultural activities that are responsible for higher pollution emissions. The Pakistan agricultural sector contributes a 39% share of national GHG emissions, according to the 2008 National GHG Inventory (Khan et al. 2011). Recently, the Government of Pakistan (2020) highlighted that “the agriculture sector is the second largest sector contributing to GHG emissions (174 out of 406 Mt CO₂Eq).” Such high rates of emissions in the agriculture sector call for immediate response.

Another important issue with the agriculture sector is the share of population and labor force in the agriculture sector which is secularly declining over the years. Moreover, the share of agriculture in GDP is also declining over time (Üngör 2013). In the case of Pakistan, the share of agriculture in GDP is also declining. Particularly, with the present pandemic of COVID-19, the agricultural sector is facing deagriculturalization (Government of Pakistan 2020). The share of employment in the agriculture sector has declined from 46% in 1990 to 37% in 2019. Similarly, the share of agriculture in Pakistan’s GDP has declined from 46% in 1960 to 23% in 2019 (World Bank 2020). The pattern of deagriculturalization in Pakistan is given in Fig 1.

The existing studies suggest various agricultural practices that contribute to environmental changes. Pretty (2008)

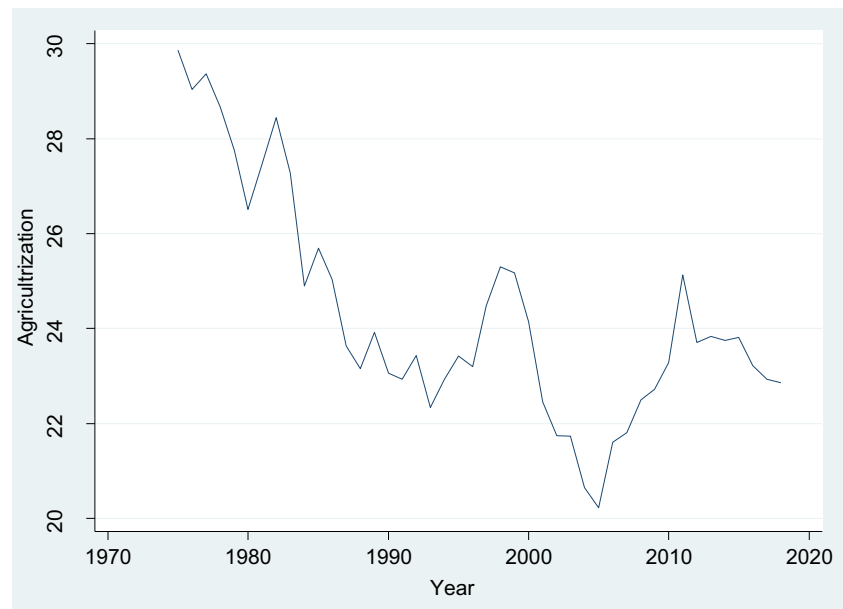
argued that the relationship of agriculture with the environment depends upon agricultural practices. Agriculture can increase CO₂ emissions if organic waste is accrued in the soil. On the contrary, agriculture can help to lower carbon emissions if such waste is exhausted as an energy source rather than burning fossil fuel. Moreover, in the presence of sustainable agricultural practices, food production increases, pesticide applications decline, and carbon emissions are balanced out.

Many studies have investigated the impact of the agricultural ecosystem on environmental quality. These studies have employed multiple linear regression models, meta-analyses, and linear mixing models. Couwenberg et al. (2010) explored the impact of peat soil, rice paddies, and fertilizers on carbon emissions for Southeast Asia using meta-analysis. Their study showed that peatland rewetting increased CH₄ and CO₂ emissions. Hughes et al. (2011) explored the positive influence of fungicide treatment on environmental quality for the UK. Zhang et al. (2015) employed linear models for China and highlighted the impact of a crop harvest, crop residues, and process of the crop on carbon emissions. They found out that crop residues stimulate pollution emissions. Hence, Zahoor et al. (2014) concluded that nitrous contributes to pollution emissions and causes global warming.

Hou et al. (2015) investigated the influence of mitigation technologies on NH₃ and other GHG emissions using the meta-analysis method. Their findings suggest that livestock increases global emissions. However, its effect turns out to be the opposite when farm management is improved. Similarly, Mohamad et al. (2016) explored the relationship of diverse agricultural practices such as land use, inputs, and social management with environmental quality. They concluded that better management of agricultural practices improves environmental quality. In another study, Mariantonietta et al. (2018) analyzed the relationship between livestock amount and GHG emissions. They argued that livestock amounts can have both positive and negative effects on emissions depending on the quality of resource management. Livestock production leads to emission when farm handling is inefficient, while emissions lower when farms follow well-organized and planned resource management practices.

Also, Reynolds et al. (2015) examined the linkage between agricultural productivity and carbon emissions for sub-Saharan African and South Asian economies. The empirical findings concluded that the agricultural process is negatively associated with carbon emissions in both regions. Besides, the results highlight that proper agricultural management systems, proper crop cultivation, and harvest system improve the environmental quality in developing economies. Önder et al. (2011) indicated the agricultural process revealed a positive and negative effect on the environment. The positive effect comes from the provision of natural life, increasing the level of oxygen in the atmosphere by photosynthesis, while a

Fig. 1 Pattern of deagriculturalization in Pakistan



negative effect comes from dependence on pesticides, fertilizer, soil stubble burning, and plant hormone usage. Stolze et al. (2000) argued that agriculture can improve or degrade the environment depending upon the type of farming. In the case of organic farming, the environment tends to improve because of low dependency on high energy-consuming feedstuffs and chemical fertilizers.

The aforementioned discussion suggests that the available literature has certain flaws. First, the studies do not provide a clear conclusion on the relationship of agriculture with environmental quality. The results are sensitive to the study sample, datasets, and econometrics techniques. Further, the results are sensitive to country-specific agricultural practices. Second, the studies have used linear models of estimation ignoring the hidden nonlinear relationships. It is not necessary that both positive and negative shocks in agriculturalization have linear effects on economic growth environmental quality. Therefore, it is important to estimate the asymmetric effects of changes in agriculturalization on growth and the environment. Third, empirical analysis in the context of Pakistan is overlooked.

This study extends the literature by empirically investigating the dynamic relationship of deagriculturalization with economic growth and CO₂ emissions in Pakistan from the period 1975 to 2018. Unlike previous studies, this study employs a nonlinear autoregressive distributed lag (NARDL) model and Granger causality approach to examine the long- and short-run asymmetries. It is expected that the findings of this research will offer suitable policy choices to manage environmental quality and sustainable economic growth in Pakistan and other countries with similar agricultural profiles.

The remaining study is structured as follows: “[Literature review](#)” provides a brief discussion of the relevant literature. A

discussion on method and model has been provided in “[Agriculturalization and CO₂ emissions.](#)” The data description and sources are provided in “[Model and method.](#)” Empirical results and discussion are presented in “[Empirical results.](#)” Finally, “[Conclusion and policy implication](#)” provides a conclusion and policy implication.

Literature review

Various studies have elaborated on the decline in agricultural production due to the decrease in the share of the agricultural population and labor force which has a negative impact on the national income of the economy (Johnston 1970; Gollin 2010; Barrett et al. 2010). The share of agricultural employment remains high at the initial stage of economic development and then continuously declines through the entire process of development. For instance, employment in the agricultural sector in the USA was approximately 74% in 1800 and continuously declined to 2% in 2000 (Dennis and İşcan 2011).

Besides, the decline in agricultural productivity is the major challenge in the agricultural sector and is the loss of agricultural land. Around the globe, every year, three million hectares of land are lost because of soil degradation, and the land becomes unusable due to soil erosion; soil erosion is when the component of soil moves from one location to another through the water and air. Besides, 4 million hectares of land have been lost every year when the agricultural land has been converted into land used for factories, housing, and urban needs. In the USA, approximately 140 million hectares of agricultural land are lost in 30 years because of soil erosion and cultivation for urban use. Additionally, it is estimated that 40 million hectares of land are in danger in the USA due to soil

erosion by the water and air. If this land is lost, it is more difficult for people to find land, and the price is high.

Further, the deagriculturalization in Pakistan due to several reasons, for instance, the total agricultural land in Pakistan is 79.6 million hectares and out of which, only 23.7 million hectares of land is cultivated; it means that 28% of the land is only used for cultivation, and approximately 8 million hectares of land is idle and unutilized. Another reason for the low agricultural productivity is waterlogging and salinity, both adversely impacting agriculture, declining agricultural productivity per hectares. Unskilled labor and the use of outdated technology and inadequate infrastructures such as road, sanitation, transport, and health facilities are the causes for low agricultural productivity; the availability of electricity in Pakistan at the rural level is around $\frac{3}{4}$ of the people. The other most important factor responsible for reducing agricultural productivity is the division of land under the law of inheritance; landholding is subdivided over and over again, so landholding is scattered. It is very difficult to use modern machinery on very small pieces of land and so on. These are factors are responsible for the deagriculturalization in Pakistan.

A number of past studies have demonstrated the linkage between agricultural productivity and economic growth particularly in the developing economies which are trying to achieve sustainable development goals. Plenty of country-specific studies demonstrate the export-led growth hypothesis in the panel, and cross-sectional studies are available for different regions based on various types of econometric techniques, providing different turnouts in the twentieth century. Numerous studies have investigated the linkage between agricultural export and output growth for various regions (e.g., Kormendi and Meguire 1985; Balassa 1978; Chenery and Strout 1966; Michaely 1977; Heller and Porter 1978). The empirical findings depict that agricultural export reveals a positive and significant impact on output growth (McKinnon 1964; Helpman and Krugman 1985), and empirical results highlight that agricultural exports both direct and indirect ways show a positive impact on output growth via the efficient utilization of natural resources, especially in the developing economies. Most of the empirical findings concluded that agricultural export indicates a strong and positive impact on output growth of the concerned economies (Ram 1987; Balassa 1978; Voivodas 1973).

Kavoussi (1984) examined the nexus between agricultural export and output growth by employing a panel dataset of 73 developing economies using a simple regression analysis over the period 1960–1978. The empirical turnout depicts that agricultural exports contribute to enhancing the output growth to the high-income economies. Additionally, the results demonstrate a positive linkage between agricultural export and output growth both in low- and middle-income countries. Besides, in developing economies, primary export is an important driver for output growth.

Similarly, Darrat (1987) and Marshall (1890) investigated the bidirectional and unidirectional causal linkage between agricultural export and output growth by employing the Granger causality estimation technique. For instance, Ekanayake (1999) adopted a cointegration and error correction econometric technique to explore the nexus between agricultural export and output growth over the period 1960–1997 in Asian economies such as Thailand, Pakistan, Sri Lanka, Philippines, India, and Korea. The empirical finding concluded that there exists a bidirectional linkage between agricultural export and output growth in these Asian countries. Also, the empirical results demonstrate both in the short- and long-run causal nexus between agricultural and output growth instead of Sri Lanka.

However, Tiffin and Irz (2006) examined the causal nexus between agricultural output and GDP based on a panel of 85 economies over the period 1960–1971. The empirical finding elaborates that agricultural output contributes to stimulating output growth in developing economies but does not find any evidence for developed nations. Malik (2010) depicted that agricultural export stimulates output growth for Pakistan. Shombe (2008) described the nexus between manufacturing industry, export, and agricultural output growth for Tanzania over the period 1970–2005. The empirical findings elaborate on the presence of causal bidirectional nexus between the agricultural sector and export growth; in contrast, the results confirm the unidirectional causal nexus between the agricultural sector to the manufacturing sector. Shaikh (2011) concluded that inefficient export policies did not contribute to output growth. Pistoiesi and Rinaldi (2011) demonstrated the effect of agricultural export and output growth in Italy over the period 1863–2004 by employing cointegration and Granger causality technique. The empirical results indicate that the long-run linkage exists between the variables. Faridi (2012) investigated the nexus between agricultural export and output growth for Pakistan over the period 1972–2008. The empirical results from causality indicate that a bidirectional causality is running between nonagricultural export and output growth. Besides, export does not indicate a significant and positive impact on output growth for Pakistan.

Gilbert et al. (2013) highlighted the linkage between agricultural export and output growth for the period 1975–2009 by employing the Cobb-Douglas production function. The empirical turnouts indicate that there is an inconclusive impact of export on output growth for the Cameroon economy. Bulagi et al. (2015) investigated the nexus between agricultural export and output growth for the African economy. The empirical findings demonstrate that agricultural export stimulates output growth in the African countries; on the other hand, agricultural export shows a negative impact on net factor income. Ijirshar (2015) explored the relationship between agricultural export, inflation, real exchange rate, trade, and output growth for the period 1970–2012 for the

Nigerian economy. The empirical findings concluded that agricultural export stimulates output growth both in the short and long run in the Nigerian nation. Kang's (2015) finding was similar in the Asian states such as Pakistan, Vietnam, Thailand, and India. In line, Verter and Bečvářová (2016) examined the linkage between agricultural export and output growth for the period 1980–2012 by employing ordinary least squares (OLS) for Nigeria. The findings revealed that agricultural export enhances output growth while these result in the same line for instance (Abbas 2012; Quddus and Saeed 2005; Haleem et al. 2005; Bashir and Din 2003; Shahbaz et al. 2015) for Pakistan.

Agriculturalization and CO₂ emissions

The agricultural sector plays a key role in the economic system. It has widely accepted that greater productivity and higher output growth in the agricultural sector substantially enhance the overall economic growth in the concerned economy. The agricultural sector supports the country in various aspects, for instance, the supply of raw material to the industry. This sector also improves the country's competitiveness and contributes to international trade by offering a substantial part of both export and import, earning foreign exchange for the country by the export and creating jobs for a significant proportion of the nation's population.

Further, with all its contribution to society and the economy, agricultural farming has a negative impact on environmental quality. Soil may be harmed by changes in land uses, the practice of farming of uncultivated land, ignoring the soil conservation technique and overgrazing. Additionally, the quality of water has increased by agriculture by the contamination of both groundwater and surface caused by substantial production and use of chemical fertilizer. Hence, the increase in agricultural productivity leads to an increase in energy consumption, primarily relying on fossil fuels (Tabar et al. 2010), contributing to an emitted high concentration of carbon emission in the atmosphere and causing global warming (IPPC 2013), deteriorating the water quality, deforestation, and pollution. Besides, the earlier stages of crop production remove carbon emissions from the environment by the photosynthesis and transfer it into the soil and plants; by the later stages of crop growth, carbon emissions have been discharged back to the environment through the plant and soil respiration which enhances the carbon emissions and global warming. For these reasons, the detrimental impact of agriculture should be examined carefully to establish a much efficient policy framework.

The environment indicates humidity level, precipitation, atmosphere pressure, air temperature, cloud covers, sunshine intensity, and wind flows. The change in atmosphere as compared to earlier is known as climate change. Additionally, weather equilibrium is persistently stable by the local

ecosystem, carbon emissions, nitrogen cycle, and water (Abas and Khan 2014; Abas et al. 2017). With the passage of time, atmospheric changes are caused by GHG emissions; in the short run, climate changes are occurring in the environment. Carbon emissions (CO₂), ozone (O₃), nitrous oxide (N₂O), methane (CH₄), and water vapor (H₂O) are the basic atmospheric pollutions on the planet (Karl and Trenberth 2003). And these gases emitted a high concentration of gases in the environment which may cause global warming and could result in climate change (Ramachandra et al. 2015). Pre-industrialization and human activity are the major causes of global warming and the increase in the temperature of the Earth. Also, the major share of pollution emissions comes from CO₂ (76%), F gases (2%), NO₂ (6%), and CH₄ (16%) (Abas et al. 2017). But the major cause of pollution emissions comes from carbon emissions which are responsible for global warming (Li and Yang 2016). For the past few decades, global warming became the most debatable topic because of environmental hazards (Fereidouni 2013).

A number of recent studies indicate that 10 to 15% of pollution emissions come from the agricultural sector (Muller et al. 2011). Pakistan is an agricultural country, and the agricultural sector and livestock stimulate 19.8% of the GDP and generate 42.3% of employment. Also, most developing economies primarily rely on the agricultural sector; agricultural productivity leads to the stimulation of pollution emissions and causes environmental degradation (Khan and Abas 2012). The national GHG inventory depicts that 39% of pollution emissions come from the agricultural sector in Pakistan. The higher share of pollution emissions comes from the agricultural sector, and it attracts quick attention (Khan et al. 2011).

Both the agricultural sector and the natural environment substantially are related to each other. Besides, the main source of pollution emissions comes from the agricultural sector, such as the burning of crop residues, management of manure, fermentation, management of soil, and rice cultivation (Ramachandra et al. 2015). The major crop of Pakistan is the cultivation of rice; it contributes 6% of pollution emissions and 2.1% of emissions come from agricultural soil. These pollution emissions come from water mismanagement, inefficient fertilizer applications, and various agricultural activities that are responsible for higher pollution emissions. Kim et al. (2016) explore that agricultural productivity stimulates pollution emissions directly and a substantial source of global warming. For instance, previous studies (Lin and Fei 2015; Couwenberg et al. 2010) investigate the linkage among peat soil, fertilizer, and pollution emissions for Southeast Asia. The empirical findings concluded that peat soil mitigates pollution emissions.

Hughes et al. (2011) examine the nexus between fungicides and pollution emissions. The empirical results indicate that the treatment of fungicides decreases pollution emissions. Shcherbak et al. (2014) demonstrated the impact of

agricultural soil on pollution emissions, and the findings concluded that it enhances carbon pollution. Zhang et al. (2015) employed mixing linear models and highlighted the impact of crop harvests, crop residues, and processes of the crop on emissions. The turnout depicts that crop residues stimulate pollution emissions. Hou et al. (2015) investigate the linkage between NH₃ and pollution emissions by using a meta-analysis estimation procedure. The empirical results indicate that the manure of livestock shows a positive impact on pollution emissions, while the results highlight that an efficient farm management system mitigates the pollution emissions. Mohamad et al. (2016) examine the impact of agricultural activity on carbon emissions. The empirical finding concluded that agricultural activity shows a significant and positive impact on emissions. Mariantonietta et al. (2018) indicate that livestock activities lead to an increase in environmental pollution. Additionally, Vetter et al. (2017) state that agricultural activities are the main source of global warming. The rapid increase in the population increases the demand for agricultural productivity and an increase in environmental pollution. Besides, the results indicate that rice and livestock are the major causes of pollution emissions as compared to other cereal production.

Hence, Zahoor et al. (2014) investigate the impact of nitrous fertilizer used in crops on pollution emissions. The results concluded that nitrous contributes to pollution emissions and causes global warming. Also, Reynolds et al. (2015) examine the linkage between agricultural productivity and carbon emissions for sub-Saharan Africa and South Asian economies. The empirical findings concluded that the agricultural process is negatively associated with carbon emissions in both regions. Besides, the results highlight that proper agricultural management systems, proper crop cultivation, and harvest system improve the environmental quality in developing economies. Pretty (2008) states that if organic waste is used instead of fertilizer, it protects the environment and also increases agricultural productivity. Önder et al. (2011) indicate the agricultural process revealed positive and negative effects on the environment. The positive effect comes from the provision of natural life, increasing the level of oxygen in the atmosphere by photosynthesis, while a negative effect comes from dependence on pesticides, fertilizer, soil stubble burning, and plant hormone usage. Stolze et al.'s (2000) empirical findings concluded that agricultural activities lead to an increase in pollution emissions and degrade the environment. The summary of the literature review is given in Table 1.

Model and method

The agriculture sector plays an important role in feeding the global population and helps the rural livelihood in the developing

world. Besides, it is regarded as the key driver of economic growth and development (Cao and Birchenall 2013). Moreover, the increasing use of petroleum products in the agriculture sector is putting immense pressure on environmental quality and posing a threat to global emission targets decided in the Kyoto protocol. Besides, agricultural practices such as chemical products, fertilizers, pesticides, and crop nutrients, are degrading environmental quality (Palaniyandi et al. 2013). Further, the growing demand for food as a result of the increasing population is promoting unsustainable practices in the agriculture sector (Lin and Xu 2018). Thus, we extended the models in the same vein in the past studies; we test the symmetric and asymmetric effects of agriculturalization on economic growth and environmental quality. The model is

$$EG_t = \varphi_0 + \varphi_1 Agr_t + \varphi_2 Urb_t + \varphi_3 EC_t + \varphi_4 FD_t + \varepsilon_t \quad (1a)$$

$$CO_{2,t} = \varphi_0 + \varphi_1 Agr_t + \varphi_2 Urb_t + \varphi_3 EC_t + \varphi_4 FD_t + \varepsilon_t \quad (1b)$$

In Eqs. (1a and 1b), EG_t is a measure of economic growth, CO_2 is a measure of environmental quality, Agr_t is agricultural value-added, Urb_t is the total population in urban areas, EC_t is the energy consumption in an economy, and FD_t is the financial development. Specification (1a and 1b) is given on the long-run yields of agriculturalization effects on economic growth and environmental quality. In order to imply their short-run effects, therefore, we must add the short-run dynamic adjustment process in the error-correction equation (1a and 1b). The specifications are

$$\begin{aligned} \Delta EG_t = & \alpha_0 + \sum_{i=1}^p \pi_i \Delta EG_{t-i} + \sum_{i=0}^p \psi_i \Delta Agr_{t-i} \\ & + \sum_{i=0}^p \pi_i \Delta Urb_{t-i} + \sum_{i=0}^p \theta_i EC_{t-i} + \sum_{i=0}^p \lambda_i FD_{t-i} \\ & + \omega_1 EG_{t-1} + \omega_2 Agr_{t-1} + \omega_3 Urb_{t-1} \\ & + \omega_4 EC_{t-1} + \omega_5 FD_{t-1} + \lambda.ECM_{t-1} + \varepsilon_t \end{aligned} \quad (2a)$$

$$\begin{aligned} \Delta CO_{2,t} = & \alpha_0 + \sum_{i=1}^p \pi_i \Delta CO_{2,t-i} + \sum_{i=0}^p \psi_i \Delta Agr_{t-i} \\ & + \sum_{i=0}^p \pi_i \Delta Urb_{t-i} + \sum_{i=0}^p \theta_i EC_{t-i} + \sum_{i=0}^p \lambda_i FD_{t-i} \\ & + \omega_1 CO_{2,t-1} + \omega_2 Agr_{t-1} + \omega_3 Urb_{t-1} \\ & + \omega_4 EC_{t-1} + \omega_5 FD_{t-1} + \lambda.ECM_{t-1} + \varepsilon_t \end{aligned} \quad (2b)$$

In Eqs. (2a and 2b), we define short-run effects by the delta variables and long-run effects by estimates of $\omega_2 - \omega_5$ divided by ω_1 . The benefit of Eqs. (2a and 2b) is that short- and long-run effects are considered in a single step. To avoid a spurious

Table 1 Summary of literature review

Authors	Region	Time	Techniques	Variables	Outcomes
Ehui and Tsigas (2009)	Nigeria	2001–2005	CGE model	Agriculture growth & GDP	Positive
Awunyo-Vitor and Sackey (2018)	Ghana	1975–2017	ECM	Agricultural export + with GDP	Positive
Msuya (2007)	Tanzania	1992–2005	Regression analysis	Agricultural FDI & GDP	Positive
Sanjuán-López and Dawson (2010)	42 economies	1970–2004	Granger causality	Agriculture growth & GDP	Positive
Levin and Raut (1997)	Newly industrialized states	1965–1984	Robust analysis	Agriculture growth & GDP	Positive
Dawson (2005)	Developed economies	1974–1995	FE and RE	Agriculture growth & GDP	Positive
Cao and Birchenall (2013)	China	1991–2009	OLS	Agriculture growth & GDP	Positive
Tiffin and Irz (2006)	85 economies	1960–1971	Granger causality	Agriculture growth & GDP	Positive
Abou-Stait (2005)	Egypt	1977–2003	Granger causality	Agriculture growth & GDP	Positive
Kavoussi (1984)	73 developed states	1960–1978	Regression analysis	Agriculture growth & GDP	Positive
Olalekan and Simeon (2015)	Nigeria	1990–2014	Probit model	Agriculture growth & GDP	Positive
Malik (2007)	Pakistan	1961–2000	ECM and VECM	Agriculture growth & GDP	Positive
Oyakhilomen and Zibah (2014)	Nigeria	1970–2011	ARDL	Agriculture growth & GDP	Positive
Zheng et al. (2019)	China	1996–2015	ARDL	Agriculture productivity & CO ₂	Positive
Xu and Lin (2017)	China	2005–2014	Weighted regressions	Agriculture productivity & CO ₂	Positive
Waheed et al. (2018)	Pakistan	1990–2014	FMOLS	Agriculture productivity & CO ₂	Positive
Raheem et al. (2019)	Iran	1987–2015	Granger causality	Agriculture productivity & CO ₂	Positive
Zafeiriou and Azam (2017)	France	1992–2014	ARDL and ECM	Agriculture productivity & CO ₂	Positive
Qiao et al. (2019)	G-20 economies	1990–2014	FMOLS and VECM	Agriculture productivity & CO ₂	Positive
Liu et al. (2017)	Asian economies	1970–2013	FMOLS and VECM	Agriculture productivity & CO ₂	Positive
Lin and Xu (2018)	China	2001–2015	Qunitile-Qunitile regression	Agriculture productivity & CO ₂	Positive
Khan et al. (2011)	Pakistan	1981–2015	FMOLS and VECM	Agriculture productivity & CO ₂	Negative
Jebli and Youssef (2017)	Sudan, Morocco, Algeria	1980–2011	Granger causality	Agriculture productivity & CO ₂	Negative
Jebli and Youssef (2017)	Brazil	1980–2011	ARDL	Agriculture productivity & CO ₂	Positive
Asumadu-Sarkodie and Owusu (2017)	Ghana	1961–2012	Granger causality	Agriculture productivity & CO ₂	Positive
Jebli and Youssef (2017)	Morocco	1980–2013	ARDL	Agriculture productivity & CO ₂	Positive
Jebli and Youssef (2017)	Tunisia	1980–2011	Granger causality	Agriculture productivity & CO ₂	Positive
Liu et al. (2017)	BRICS	1992–2013	FMOLS	Agriculture productivity & CO ₂	Positive
Zhangwei and Xungangb (2011)	Sichuan provinces of China	1997–2008	OLS	Agriculture productivity & CO ₂	Positive
Saravia-Matus et al. (2019)	Latin American states	1990–2015	Decoupling elasticities	Agriculture productivity & CO ₂	Positive

regression issue, Pesaran et al. (2001) suggest two tests for cointegration. The first is the F test and the second is the *t* test to establish the cointegration, while they tabulate new critical values for cointegration in the model. Indeed, under this method, dependent, independent, and control variables could be a combination of I(0) and I(1); there is no necessity for pre-unit-root testing. Recently, Shin et al. (2014) announced asymmetric cointegration by modifying the specifications (2a and 2b). Given that our variable of concern is agriculturalization, following their approach, we first form ΔAgr which includes positive values reflecting agriculturalization and negative values which reflect deagriculturalization. Therefore, we generate two new time series variables as follows:

$$Agr^+_t = \sum_{n=1}^t \Delta Agr^+_t = \sum_{n=1}^t \max(\Delta Agr^+_t, 0) \tag{3}$$

$$Agr^-_t = \sum_{n=1}^t \Delta Agr^-_t = \sum_{n=1}^t \min(\Delta Agr^-_t, 0) \tag{4}$$

where Agr⁻_t (Agr⁺_t) is the partial sum of negative (positive) changes and reflects only a decrease (increase) in agriculturalization. We then shift back to Eqs. (2a and 2b) and replace Agr_t with the two partial sum variables to arrive at

$$\begin{aligned} \Delta EG_t = & \alpha_0 + \sum_{i=1}^p \pi_i \Delta EG_{t-i} + \sum_{i=0}^p \delta_i \Delta Agr^+_{t-i} \\ & + \sum_{i=0}^p \phi_i \Delta Agr^-_{t-i} + \sum_{i=0}^p \pi_i \Delta Urb_{t-i} + \sum_{i=0}^p \theta_i EC_{t-i} \\ & + \sum_{i=0}^p \lambda_i FD_{t-i} + \omega_1 EG_{t-1} + \omega_2 Agr^+_{t-1} \\ & + \omega_3 Agr^-_{t-1} + \omega_4 Urb_{t-1} + \omega_5 EC_{t-1} \\ & + \omega_6 FD_{t-1} + \lambda.ECM_{t-1} + \varepsilon_t \end{aligned} \tag{5a}$$

$$\begin{aligned} \Delta CO_{2,t} = & \alpha_0 + \sum_{i=1}^p \pi_i \Delta CO_{2,t-i} + \sum_{i=0}^p \delta_i \Delta Agr^+_{t-i} \\ & + \sum_{i=0}^p \phi_i \Delta Agr^-_{t-i} + \sum_{i=0}^p \pi_i \Delta Urb_{t-i} \\ & + \sum_{i=0}^p \theta_i EC_{t-i} + \sum_{i=0}^p \lambda_i FD_{t-i} + \omega_1 CO_{2,t-1} \\ & + \omega_2 Agr^+_{t-1} + \omega_3 Agr^-_{t-1} + \omega_4 Urb_{t-1} \\ & + \omega_5 EC_{t-1} + \omega_6 FD_{t-1} + \lambda.ECM_{t-1} + \varepsilon_t \end{aligned} \tag{5b}$$

Error-correction models such as Eqs. (2a and 2b) are commonly known as nonlinear or asymmetric ARDL, and the asymmetric supposition is introduced through partial sum variables. However, models, such as Eqs. (2a and 2b), are known as linear or symmetric ARDL. Shin et al. (2014) exhibit that both the symmetric and asymmetric models are subject to the same diagnostics tests. Once Eqs. (5a and 5b) is estimated by OLS or any other, we can examine a few asymmetry propositions. First, based on the lag selection criterion, if partial sum variables take a different lag order in the short run, it means dynamics adjustment asymmetry will be established. Second, short-run effects of agriculturalization on economic growth and environmental quality will be asymmetric if at any given lag (i), the estimate of δ_i are different from the estimate of ϕ_i . By employing the Wald test, we can test the short- and long-run dynamics adjustment asymmetric effects of agriculturalization on economic growth and environmental pollution.

Data

The present study used a time series dataset for the period 1975–2018 to investigate the deagriculturalization symmetric and asymmetric impacts on both economic growth and carbon dioxide emissions for Pakistan. As Rodrik (2016) used industrial value-added as a proxy for deindustrialization, so we can employ agricultural value-added as a proxy for deagriculturalization in our study. The independent variables are agricultural value-added (Agr), urbanization (Urb), energy consumption (EC), and financial development (FD), while the dependent variables are economic growth (EG) in model one and carbon dioxide emissions (CO₂) in model two. The data of all the selected variables are obtained from the World Development Indicators (WDI). Data sources, details of descriptive statistics, and variable symbols are represented in Table 2. The descriptive state's results are reported in Table 2, which indicate that the average values of EG, CO₂, Agr, Urb, EC, and FD are 2.142, 97846, 24.29, 31.94, 418, and 46.01 and the standard errors are 1.857, 53,733, 2.378, 2.996, 67.80, and 6.410, respectively.

Empirical results

In this section, we estimate economic growth and CO₂ symmetric/linear ARDL model (2a and 2b) and the asymmetric/nonlinear ARDL model (5a and 5b) by examining the deagriculturalization effects on economic growth and CO₂ over the period 1975–2018. As a pilot test, since the ARDL approaches require the variables to be a mixture of I(0) and I(1), we test for these initial properties and show the results of augmented Dickey–Fuller (ADF) and Phillips–Perron (PP)

unit root statistics in Table 3. From Table 3, economic growth and agriculturalization are stationary at I(0), and some other variables become stationary at I(1) in ADF which suggests the justification of the ARDL approach, while the PP unit root statistics are also given in Table 3.

Table 4 reports the estimates of the short run and long run of the linear and nonlinear ARDL model. In the linear ARDL economic growth model, agriculturalization has a negative effect on economic growth in the short and long run; this implies that the agricultural sector is not an important component of Pakistan's economic growth. No doubt, the agricultural sector in Pakistan is arguably resourceful, while due to the low performance of this sector, it has a negative effect on economic activity and economic growth. This finding is supported by Gollin (2010), who noted that the agrarian economy does not recommend that it must be a foremost segment for economic growth. This finding also suggests that agricultural productivity growth is neither a sufficient nor a necessary condition for economic growth in Pakistan. While deagriculturalization is also the leading cause of deindustrialization, therefore, deagriculturalization has a negative effect on economic growth. The agricultural sector productivity of Pakistan has been falling since the last decade; this implies that the agricultural sector has a dominant negative effect on economic growth, while urbanization and financial development have a positive and statistically significant effect on economic growth. Moreover, in the long run, this study also found that energy consumption has a negative effect on economic growth in the country.

In the linear carbon emissions model, agriculturalization has a negative effect on carbon emissions in Pakistan; this implies that the agricultural sector is dominant in deagriculturalization, which has a positive effect on the environment, as it reduces CO₂ emissions. This also infers that agricultural carbon emissions will decrease gradually as the agricultural economy grows a little in Pakistan. This finding is consistent with the previous study (Zhang et al. 2015) because Pakistan is one of the exceptional cases in the world. This also means that energy consumption has been gradually decreased with deagriculturalization, which has a positive effect on the environment. Another reason is governance mechanisms and markets and policies on carbon emissions will also be improved gradually; in adverse, carbon emissions are decreased. The coefficient of energy consumption shows that a 1% increase in energy consumption would lead to a 0.299% level of CO₂ emissions in the short run. However, energy consumption influence is comparatively more on carbon emissions in the long run, while urbanization has an important effect on CO₂ emissions in the long run in the case of Pakistan.

The linear ARDL model also shows the few diagnostic statistics in Table 4 in panel C. To check for autocorrelation and misspecification problems, we have applied the Lagrange multiplier (LM) and Ramsey's regression equation

Table 2 Definition and descriptive statistics

Variables	Symbol	Definitions	Mean	Std. dev.	Sources
Economic growth	EG	GDP growth (annual %)	2.142	1.857	World bank
CO ₂	CO ₂	Carbon dioxide emissions (Kilotons)	97846	53733	World bank
Agriculturalization	Agr	Agricultural value-added constant (% of GDP)	24.29	2.378	World bank
Urbanization	Urb	Share of urban residents in total population	31.94	2.996	World bank
Energy consumption	EC	Measured as energy use in kg of oil equivalent per capita	418.0	67.80	World bank
Financial development	FD	Domestic credit to the private sector (% of GDP)	46.01	6.410	World bank

specification error test (RESET). Both statistics in twin models are also insignificant, which implies that there are no problems of autocorrelation, and the models are correctly specified. The statistics of the F test and ECM or *t* test have significant evidence of cointegration existing in both models. We also have tested for the stability of parameters by applying the cumulative sum (CUSUM) and CUSUM squares tests to the residuals, which indicates the stable estimates represented as “S” in the linear ARDL model. Finally adjusted R^2 shows the goodness of fit in both linear models.

How do the economic growth and CO₂ emissions results change if we shift to estimates of the asymmetric or non-linear models in Table 4? The estimates show that agriculturalization has a negative effect on economic growth, while in adverse, deagriculturalization has an insignificant effect on economic growth in the short and long run in Pakistan. However, this outcome implies that the short- and long-term effects of the positive change in agriculturalization on economic growth are not similar to the negative shock, suggesting asymmetric effects have also existed in the short and long term. In the short and long run, urbanization has also played a significant role in economic growth. However, energy consumption has also a negative influence on economic growth in the long run.

Our estimation outcomes further show that the impact of deagriculturalization on carbon emissions is also negative which implies that deagriculturalization is also improving the environmental quality, while agriculturalization does not affect the carbon emissions in the short run. A 1% increase

(decrease) in agriculturalization causes a 0.114% (0.053%) decrease in carbon emissions. This also implies that agriculturalization has asymmetric effects on carbon emissions in magnitude but not in direction. In sum, the estimated coefficients of agriculturalization and deagriculturalization have a negative influence on CO₂ emissions; this infers that agriculturalization and deagriculturalization decrease pollution emissions in Pakistan in the long run. This also implies that deagriculturalization is reducing energy consumption, which leads to smaller levels of carbon emissions. Another reason is technological-based agriculturalization has also increased green production. The results also show that the phenomenon of deagriculturalization is dominant in Pakistan, which also slows down industrialization and economic growth, which could also reduce the energy consumption and adverse, achieving environmental quality. This also means that deindustrialization dampens the positive impact of agriculture on environmental quality. In 2008, the share of the agricultural sector to national GHG emissions contributes 39% in Pakistan, while this share is sharply decreased day by day due to deagriculturalization. The main sources of agricultural carbon emissions are livestock, rice cultivation, soil management, manure management, enteric fermentation, chemical fertilizer, and burning of crop residues, which suggests that these factors are not much harmful to carbon emissions in Pakistan. Similarly, urbanization has a positive effect on carbon emissions; this suggests that urbanization increases the consumption of polluting energy that is one of the basic sources of carbon emissions.

Table 3 Unit root test results

Variables	ADF test statistics			PP test statistics		
	I(0)	I(1)	Decision	I(0)	I(1)	Decision
EG	-2.632*		I(0)	-2.605*		I(0)
CO ₂	-1.288	-3.963***	I(1)	-1.108	-3.761***	I(1)
Agr	-2.614*		I(0)	-2.591*		I(0)
Urb	-1.241	-4.625***	I(1)	-1.345	-3.892***	I(1)
EC	-1.019	-3.982***	I(1)	-1.172	-3.982***	I(1)
FD	-1.105	-3.456***	I(1)	-1.210	-3.974***	I(1)

Table 4 ARDL and NARDL coefficient estimates

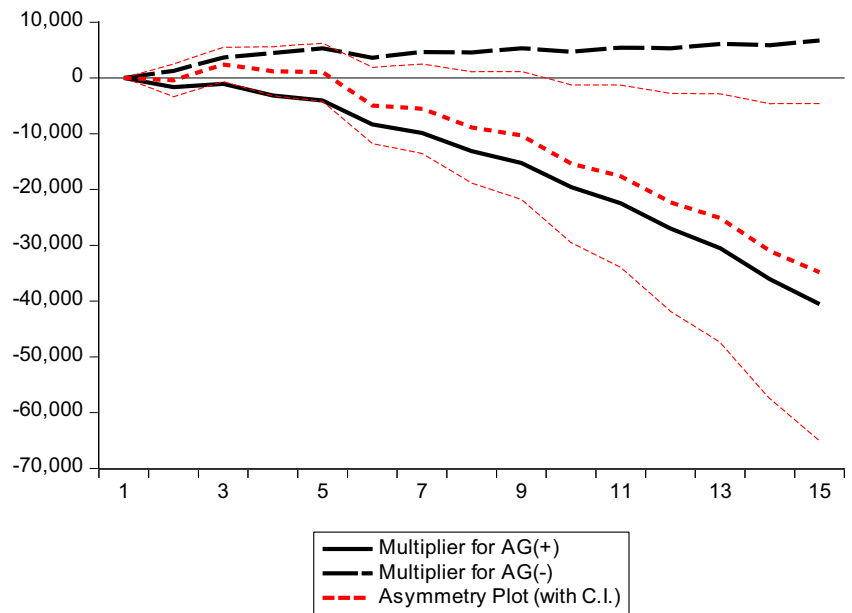
	ARDL				NARDL			
	Economic growth		CO ₂		Economic growth		CO ₂	
	Coefficient	<i>t</i> stat	Coefficient	<i>t</i> stat	Coefficient	<i>t</i> stat	Coefficient	<i>t</i> stat
Short run								
ΔAgr_t	-0.610*	1.757	-0.012**	3.465				
ΔAgr_t^+					-1.490**	2.671	-0.001	0.117
ΔAgr_{t-1}^+							0.014	1.393
ΔAgr_{t-2}^+							0.017	1.615
ΔAgr_t^-					0.551	1.134	-0.018**	2.741
ΔUrb_t	-3.581	0.189	0.016	1.318	4.002**	2.695	0.087**	2.435
ΔUrb_{t-1}	-6.837**	2.497						
ΔUrb_{t-2}	6.873**	2.951						
ΔEC_t	-0.883	0.080	0.299**	2.338	4.068	0.330	0.333**	1.993
ΔEC_{t-1}	1.486	0.111			4.328	0.983	0.414**	2.061
ΔEC_{t-2}	7.115	0.555			2.588*	1.843		
ΔEC_{t-3}	3.990**	3.227						
ΔFD_t	1.008	0.214	0.069	1.324	0.124	0.035	-0.026	0.448
Long run								
Agr	-0.754**	4.364	-0.052**	3.077				
Agr_t^+					-1.259**	2.641	-0.114**	2.332
Agr_t^-					-0.143	0.523	-0.053**	3.912
Urb	1.217**	3.867	0.070*	1.845	3.382**	2.631	0.260**	2.582
EC	-1.014**	6.086	1.345**	2.602	-3.879**	4.320	-0.105	0.162
FD	4.133**	2.121	0.310	1.154	0.105	0.035	-0.079	0.471
C	9.806**	5.571	1.285	0.491	5.017**	3.021	4.072**	2.091
Diagnostic-stat								
F-test	6.74**		4.64*		5.64**		7.43**	
ECM(-1)	-0.581**	5.489	-0.222**	3.688	-0.683**	7.012	-0.334**	2.803
LM test	1.15		1.23					
RESET	0.98		1.02					
Adj-R2	0.93		0.94					
CUSUM	S		S		S		S	
CUSUM squares	S		S		S		S	
Wald test-SR					3.85**		4.53**	
Wald test-LR					5.35**		6.24**	

Note: * and ** denote 10% and 5% levels of significance, respectively. The critical values of RESET, LM, and Wald tests at the 10% level of significance is 2.70 and at 5% level of significance is 3.84

In order to see the validity of our nonlinear results, we have applied various diagnostic statistics in Table 4 in panel C. F statistics are also statistically significant in nonlinear economic growth and carbon emissions models, which implies long-run results are cointegrated. Similarly, long-run estimates are also cointegrated because $ECM_t - 1$ or *t*-test statistics are also negatively significant at 5% with a value -0.683 in the economic growth model, while it is significant at 5% and with a value -0.683 in the carbon emissions model. Some extra diagnostic tests are also performed in nonlinear models, e.g., the test of serial correlation (LM),

test of misspecification (RESET), and tests of parametric instability (CUSUM and CUSUM of squares). The LM and RESET tests have insignificant statistics at χ^2 distribution with one degree of freedom. This infers that our nonlinear models are free from autocorrelation and models are correctly specified, while CUSUM and CUSUM of square estimates revealed that almost all our models are stable. However, the validity of asymmetric short- and long-run effects in the twin model is also confirmed through the Wald test, which shows the existence of asymmetries in all estimates.

Fig. 2 Asymmetric dynamic multipliers effects of deagriculturalization on economic growth



Finally, we also derived asymmetric multiplier effects of deagriculturalization on economic growth and CO₂. Figure 2 exhibits an asymmetric association between deagriculturalization and economic growth, while Fig. 3 demonstrates that asymmetries also hold between deagriculturalization and CO₂ emissions. Moreover, the positive shock remains more dominant than the negative shock in the graphs. The findings also show that deagriculturalization causes CO₂ emissions; this means that deagriculturalization would affect CO₂ emissions in Pakistan in Table 5. Additionally, we also reported detailed symmetric and asymmetric Granger causality estimates in Table 5.

Conclusion and policy implication

Pakistan is an agrarian economy, and it ranks as the fifth most populous country in the world. However, higher demand for food items in Pakistan would also require a reputable agricultural sector; in adverse, Pakistan is facing the deagriculturalization phenomena in the last few decades. The share of agriculture in total employment, which was initially very large, has undergone a continuous decline throughout the entire path of economic development in the last decades in Pakistan. Under these circumstances, economic growth and environmental pollution in Pakistan are drastically decreased. The objective of our study is to examine the

Fig. 3 Asymmetric dynamic multipliers effects of deagriculturalization on CO₂ emission

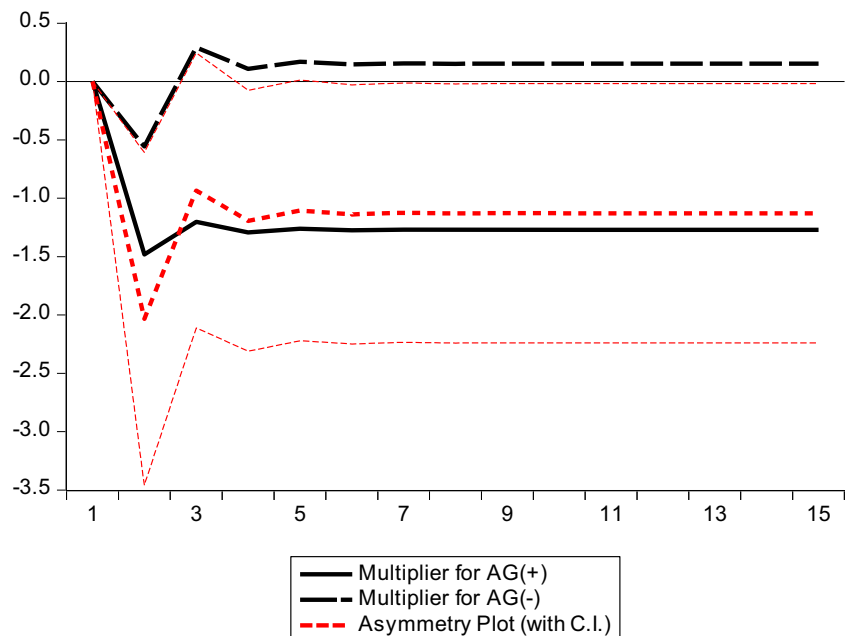


Table 5 Results of symmetric and asymmetric causality test in Pakistan

	F-statistic	Prob.		F-statistic	Prob.
$Agr_t^+ \rightarrow CO_2$	1.330	0.277	$Agr_t^+ \rightarrow FD$	5.097**	0.011
$CO_2 \rightarrow Agr_t^+$	2.561*	0.091	$EG \rightarrow Agr_t^-$	0.082	0.921
$Agr_t^- \rightarrow CO_2$	3.849**	0.031	$Agr_t^- \rightarrow EG$	1.180	0.319
$CO_2 \rightarrow Agr_t^-$	1.631	0.210	$Urb \rightarrow Agr_t^-$	10.86***	0.000
$EG \rightarrow CO_2$	5.476***	0.008	$Agr_t^- \rightarrow Urb$	0.446	0.644
$CO_2 \rightarrow GDP$	0.502	0.609	$EC \rightarrow Agr_t^-$	0.467	0.630
$Urb \rightarrow CO_2$	0.646	0.530	$Agr_t^- \rightarrow EC$	4.471**	0.018
$CO_2 \rightarrow Urb$	0.320	0.728	$FD \rightarrow Agr_t^-$	0.412	0.665
$EC \rightarrow CO_2$	3.198**	0.052	$Agr_t^- \rightarrow FD$	5.131**	0.011
$CO_2 \rightarrow EC$	1.624	0.211	$Urb \rightarrow EG$	0.327	0.723
$FD \rightarrow CO_2$	0.302	0.741	$EG \rightarrow Urb$	0.159	0.853
$CO_2 \rightarrow FD$	4.324**	0.021	$EC \rightarrow EG$	1.103	0.342
$Agr_t^- \rightarrow Agr_t^+$	1.624	0.211	$EG \rightarrow EC$	2.073*	0.140
$Agr_t^+ \rightarrow Agr_t^-$	1.974*	0.154	$FD \rightarrow EG$	0.228	0.797
$EG \rightarrow Agr_t^+$	0.402	0.672	$EG \rightarrow FD$	0.659	0.523
$Agr_t^+ \rightarrow EG$	1.039	0.364	$EC \rightarrow Urb$	0.021	0.979
$Urb \rightarrow Agr_t^+$	4.672**	0.016	$Urb \rightarrow EC$	1.553	0.225
$Agr_t^+ \rightarrow UR$	2.340*	0.111	$FD \rightarrow Urb$	1.627	0.210
$EC \rightarrow Agr_t^+$	1.802	0.180	$Urb \rightarrow FD$	6.106***	0.005
$Agr_t^+ \rightarrow EC$	0.795	0.459	$FD \rightarrow EC$	0.126	0.882
$FD \rightarrow Agr_t^+$	2.940*	0.066	$EC \rightarrow FD$	2.761*	0.076

asymmetric effects of deagriculturalization on economic growth and CO₂ emissions in Pakistan by using the annual data from 1975 to 2018. To the best of our knowledge, no previous study has determined the deagriculturalization effects on economic growth and CO₂ emissions in Pakistan and the globe. The study used time series workhorse NARDL estimation methodology (Ullah et al. 2020), and also an asymmetric Granger causality test is employed to estimate the long-run cointegration, strength, and direction of the relationship among deagriculturalization, economic growth, and environmental pollution. The asymmetric ARDL test results established the existence of asymmetries among the deagriculturalization, economic growth, and environmental pollution in the short and long term. The nonlinear results estimate also deviates from the linear estimates in the analysis.

The results reveal that agriculturalization decreases carbon emissions in the short and long run, while deagriculturalization has an insignificant effect on decrease emissions in Pakistan. The asymmetric results show that agriculturalization leads to a fall in environmental pollution, while deagriculturalization also decreases the environmental pollution in Pakistan in the long run. However, similar results are also maintained in the short run, while deagriculturalization has more effects on carbon emissions compared to agriculturalization. Results of the long-run coefficients of urbanization

(energy consumption) have a positive (negative) effect on economic growth. These findings show that a 1% increase in urbanization (energy consumption) has increased by 3.382% and decreased by 3.879% in economic growth in the long run, while findings reveal that a 1% increase in urbanization has increased by 0.260% in the environmental pollution in the long run. The Granger causality test shows unidirectional asymmetric causality running from agriculturalization, deagriculturalization, and CO₂ emissions. Moreover, agriculturalization and deagriculturalization do not cause economic growth in Pakistan.

Based on these empirical outcomes, some crucial economic and environmental policies have emerged. Specifically, the facts show that the Pakistan agricultural sector is facing the problem of deagriculturalization, therefore, the government should focus on agricultural sector efficiency in the modern era because it is less effective on environmental pollution in Pakistan. Agricultural activities can be modified and should be realistic and cost effective in order to increase economic growth by lowering the environmental pollution. The massive use of artificial fertilizers should be avoided, and government and policymakers need to emphasize organic farming in Pakistan. The authority should emphasize technology-based farming that would help in the reduction of environmental pollution in Pakistan. The main reason for the environmental pollution by the agriculture sector is burning fossil fuel in the production phase, therefore, the government should focus on clean agricultural activities.

One of the reasons for deagriculturalization is high urbanization, therefore, authorities should be banned for urbanization on agricultural lands. The government can encourage agrarians to use innovative, clean environmental technologies by adopting an incentive mechanism. The government introduced an innovative technique in production that has less pollution in the agricultural sector. The outcomes of this empirical study can be a guideline and blueprint for other agrarian economies to tackle the problem of deagriculturalization for the creation of effective policies around economic growth and environmental quality. Moreover, additional empirical studies can examine the feature of threshold asymmetry to determine if threshold asymmetry holds in the nexus of agriculture, economic growth, and environmental quality.

Author contribution This idea was given by Sana Ullah. Sana Ullah, Sidra Sohail, and Muhammad Tariq Majeed analyzed the data and wrote the complete paper, while Waheed Ahmad and Sidra Sohail read and approved the final version.

Data availability The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical approval Not applicable.

Consent to participate I am free to contact any of the people involved in the research to seek further clarification and information.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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