Dynamic linkage between industrialization, energy consumption, carbon emission, and agricultural products export of Pakistan: an ARDL approach

Zaid Ashiq Khan¹ · Mansoor Ahmed Koondhar¹ · Imran Khan² · Uzair Ali¹ · Liu Tianjun¹

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Abstract

This study aims to contribute to the literature and examine the causal relationship between Pakistan's agricultural products export, industrialization, urbanization, transportation, energy consumption, and carbon emissions. For the last four decades, time-series data were used to employ short-run and long-run nexus between the selected variables by analyzing the autoregressive distributed lag model (ARDL). The Granger causality test was analyzed to estimate the causality directions. The unit root test results indicate that all the selected variables are stationary at the level and first difference. The bound test confirmed that all variables are cointegrated at a 1% significance level. Long-run estimates suggest that an increase in energy consumption will increase the export of agricultural products. An increase in urbanization, transportation, and carbon emission resulted in a decrease in agricultural products export in Pakistan. In the short run, an increase in industrialization, transportation, and energy consumption leads to an increase in agricultural products export. Increasing urbanization and carbon emission decrease the agricultural products export of Pakistan. Based on our findings, we recommend sustainable agricultural production, renewable energy consumption, low carbon emission technologies, and a green portfolio for sustainable agricultural products export.

Keywords Agricultural products exports · Carbon emissions · Industrialization · Urbanization · Pakistan

Introduction

The contribution of the agricultural sector to GDP in Pakistan gradually decreased to 19.3% in the year 2020 from 22.04% previously recorded in 2019 due to conventional farming practices, less use of agricultural technology, agricultural land degradation, poor agricultural policy, and the most important factor is Locust outbreak in Pakistan, which did serious agriculture losses, reported in the main crop production areas in Balochistan, Punjab, and Sindh provinces. According to the

initial assessment damage to over 115 thousand hectares of crops including wheat, oilseed crops, cotton, gram, fruits, and vegetables, besides grazing field losses. Even some crop losses were also reported in Khyber Pakhtunkhwa (GOP 2020), but still, agriculture is the largest sector and contributor to the national economy in terms of the livelihood of the mainstream population contingent directly or indirectly and labor participation with a 42.3% rate. This sector fetches the biggest workforce and helps to provide raw material to the utmost of the manufacturing sector. However, this sector can upsurge its share in the GDP due to its potential by the utilization of the latest agricultural technologies. This sector is capable to produce for domestic population use and surplus production for exports and will result to ensure food security and foreign exchange earnings. This improvement can help achieve poverty alleviation and may enrich the socio-economic structure of a major portion of the population. The major challenges to the sector include pest attacks, urbanization, climate change, and water scarcity retained production far less than the potential (GOP 2020). Growth in the agricultural sector is depending upon favorable weather conditions.

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✉ Liu Tianjun
ltj168168@nwsuaf.edu.cn

¹ College of Economics and Management, Northwest A & F University, Yangling 712100, Shaanxi, China

² Department of Economics, University of Haripur, Haripur, Khyber Pukhtunkhwa 22620, Pakistan

There is a strong relationship between agriculture and climate, precipitation, temperature, and other aspects of weather that eventually influence economic performance, such as agricultural production, commodity prices, and, finally, economic growth (Khan et al. 2020a).

Pakistan's climate is very suitable for the production of major cereal crops, such as maize, wheat, rice, cotton, and sugarcane. Wheat is above all the other cereal crops due to its production, consumption, and demand in the local market while rice is one of the major agricultural products export and contributes approximately 25% of Basmati rice export in the world (Rehman et al. 2015). Pakistani farmers are used to over applications of chemical fertilizer and pesticides which not only contributes to carbon footprints into climate but also decreases the crop production and contribution of agriculture to value-added (Koondhar et al. 2021b). Agriculture and the non-agricultural industry both are the important pillars of the Pakistan economy. The non-agricultural industries also rely upon the agricultural industry because of the raw material to produce value-added products, but by the urbanization pressure, increasing non-agricultural industrialization causes carbon emission and creates challenges for the agricultural industry. First of all, increasing non-agricultural industrialization is converting arable land to non-arable land. Secondly, industrialization intakes the labor force in large quantities and results in a shortage of labor for agriculture. Third, non-agriculture industry demand for agricultural raw material affects cropping patterns in Pakistan (Quraishi et al. 1994).

Globally, the socioeconomic transformation makes hurdles to agriculture as the rate of urbanization is increasing day by day and creating difficulties for agricultural development (Malik and Ali 2015). This unrelenting influx of rural population into cities in Pakistan had to make urban sprawl (the rapid growth of the geographic range of cities and towns to accommodate their growing population). Due to no law regarding this issue in Pakistan, the agricultural lands are getting purchased for residential and commercial purposes (Peerzado et al. 2019). As the industry is developing, transportation services are getting better, and energy consumption is increasing and ultimately resulting in environmental degradation and an increase in carbon emission. Besides, it is affecting agricultural production due to climatic changes such as a change in temperature, precipitation, and droughts. The increasing environmental pollution causes a reduction in soil fertility, increasing unseasonal weather conditions such as sudden rainfall, temperature fall, or rise that directly affects the quality and quantity of the agricultural products. It is obvious that if the quality is not good, it will not be acceptable in the international market or although the quality is enough good for international trade while the quantity is not enough it also brings challenges for agricultural products export.

Currently, pandemic COVID-19 creates unexpected challenges globally. Being a developing country Pakistan has no exception to the impacts of COVID-19, where all economic

sectors have been significantly influenced. This COVID-19 situation increases food security issues for maintaining the livelihood of the country population (GOP 2020). The logistic issues emerged during the COVID-19 situation and food supply became difficult in the country and exports of agricultural products to other countries also decreased and even stopped for some duration. That causes big monetary loss to the country's economy and also to the farmers (Yamano et al. 2020).

The primary objective of this study is to determine the impact of industrialization, urbanization, transportation, energy consumption, and carbon emissions on the agricultural products export of Pakistan using annual time-series data for the last four decades. The country's economy is significantly based on its agricultural production and its output. Our study focuses on comprehensive policies to improve the agricultural production of the country. We aim to make the following contribution to the literature. First, to the best of our knowledge and study, there is no such research that investigated the relationship among Pakistan agricultural products export and indirect factors; industrialization, urbanization, transportation, energy consumption, and carbon emissions for the longest period of time. Secondly, we employed autoregressive distributed lag (ARDL) technology; the model is more effective and can provide reliable evidence even from a small sample (Pesaran et al. 2001). Third, we expect that the study verdicts will not just heighten the literature but will also improve our understanding of the study variables linkages and ultimately help to direct the policymaking in terms of industrial transformation, urban planning, urban sprawl control, efficient energy usage, optimization of transportation structure, and mitigating carbon emission.

Literature review

In the past, empirical studies have explored the relationship between industrialization, urbanization, transportation, energy consumption, carbon emission, and agricultural production in Pakistan but no such empirical study exists which investigated the linkage of these parameters with agricultural products export. By employing the ordinary least square technique, Wagan et al. (2018) concluded that industrialization and urbanization causing loss of arable land and have a significant and negative effect on the agricultural gross domestic product (GDP) which results in a less agricultural contribution to Pakistan GDP. Industrialization and agriculture both are important economic pillars of Pakistan and both are correlated with each other. Industrialization affects agricultural production in the long run suggested by the ARDL model using annual time-series data over the period 1971–2009 for Pakistan, while agriculture affects industrialization in the long- and short-run having a bidirectional relationship (Hye 2009).

The augmented urbanization process in Pakistan like the other developing countries witnessed serious challenges

(Mughal 2019). According to the study of Malik and Ali (2015) using OLS technology concluded that urbanization has a negative and significant effect on agricultural production in the Peshawar district of Khyber Pakhtunkhwa, Pakistan. The reason is the agricultural land conversion to residential and commercial purposes reduce overall agricultural production and ultimately affect agricultural GDP. (Ho and Lin 2004) determined that urbanization along with industrialization and infrastructure (road network) development is causing a land conversion from agricultural to non-agricultural use in coastal areas of China. Another study revealed that urbanization, energy consumption, and industrialization causing environmental degradation and increasing carbon emission. The parameters are cointegrated and using a fully modified ordinary least square (FMOLS) technique shows long- and short-run relationships which finally affecting agriculture in fourteen north African and middle east countries from 1962 to 2012 (Al-Mulali and Ozturk 2015). In the case of China, a study using data over the period 1999–2018 from 27 Chinese provinces by employing dynamic common correlated effects mean group method (DCCMG) and Dumitrescu-Hurlin causality concluded that land urbanization exhibited a positive link with carbon emission growth (Ahmad et al. 2021).

Several other studies also investigated the causal linkage between urbanization, industrialization, transportation, and energy consumption with agricultural outputs. (Anees et al. 2012) examine the impact of industrialization, energy consumption, economic growth, urbanization, and carbon emission with agricultural growth in Pakistan, using vector autoregressive technique and annual time-series data over the period 1971 to 2007. The empirical evidence suggests that carbon emission affects economic growth, agriculture, and industrial development in the long-run, while industrialization and urbanization have a bidirectional granger causality relationship. A study on Pakistan for the period of 1980–2016 using ARDL bound testing along with VECM shows that oil consumption by the agriculture and power sector has a significant and positive effect on economic growth, similarly natural gas consumption by households, fertilizers, and industry sector also has a significant relationship with economic growth. While, energy consumption from oil in the households and industry sectors has a negative relationship with economic growth, and natural gas consumption in the commercial sector has a negative linkage with economic growth (Rehman et al. 2020c). The study from Saharanpur district, India using the geographic information system (GIS) technique to estimate the impact of urbanization on arable land conversion and agricultural outputs concluded that urbanization causes land damage along with a disturbance in irrigation systems causing agricultural loss (Fazal 2000).

Pakistan is among the top ten most vulnerable countries in terms of climatic change. Therefore, natural disasters, water scarcity, and floods are obvious as a consequence of climate

changes. Considering the climate changes, the contribution of carbon emission is the most highlighted. These challenges are not only causing environmental degradation but also instigating forfeiture to agricultural production in the case of Pakistan (Ahmed et al. 2016), as the study by Rehman et al. (2020b) using annual time-series data from 1988 to 2017 employed ARDL bound test and Granger causality approach for checking the dynamic linkages among the maize production and carbon emission concluded that there is a long term association as carbon emission has positive influence to maize production in Pakistan. For China decreasing carbon emission and promoting green energies in the next few decades were concluded by (Rehman et al. 2021). Another study also delivers a positive relationship between carbon emission and agricultural production in Pakistan using a generalized method of moments estimator (Qureshi et al. 2016). (Khan et al. 2019) investigated the linkage between carbon emission, energy consumption, GDP, urbanization, and agricultural export trade of Pakistan over the period 1975–2017. Rehman et al. (2019b) examine the relationship of carbon emission with energy use, cropped area, improved seed distribution, water availability, fertilizer offtake, total food grains, and gross domestic product per capita in Pakistan by using ARDL bound testing approach along with long- and short-run estimates over the period 1987 to 2017, found significant linkage of carbon emission and agricultural production in Pakistan. The empirical evidence using the cointegration technique suggests that carbon emission could be the basic factor of a decrease in the Pakistan agricultural export trade. A study on China over the period of 1982–2014 using the ARDL bounds testing approach revealed that carbon emission has a significant effect on agricultural output in both long-run and short-run analyses, while among other determinants, the land area under cereal crops, fertilizer consumption, and energy consumption has a positive and significant association with agricultural output in both long-run and short-run analysis (Chandio et al. 2020). In addition, the correlation of business, international trade, economic growth per capita, and FDI were investigated by the analysis of algorithm pathfinder keywords (Koondhar et al. 2021a).

From the dearth of literature can be seen that many researchers have investigated the carbon emission, energy consumption impact on export for different countries using time-series as well as panel data. But this study is different from the previously published researches because in this study we do not generally focus on export but we selected agricultural products export as a dependent variable and industrialization, energy consumption, urbanization, transportation, and carbon emission as independent variables, using time-series data 1976–2017 estimated ARDL model which is not previously investigated. To our best knowledge, there is no study that claims similar research for Pakistan. Figure 1 represents the theoretical framework of the study.

Fig. 1 Theoretical framework of the study

Methods and data collection

Data

The sample selected is up-to-date annual time-series data for the period from 1976 to 2017 in Pakistan; the duration of four decades was selected based on the availability of data for all proposed variables. The data was collected through secondary sources from Food and Agriculture Organization (FAO), World Development Indicators (WDI) of the World Bank, International Energy Agency (IEA), and Electronic Data

Gathering, Analysis, and Retrieval (EDGAR). The annual time-series data used in the model is presented in Table 1 and the data source information is provided at the end in the “Availability of Data” section.

The trends of all the analysis variables are shown in Fig. 2. The trend of Agricultural Products Export (APE) in 1000 US dollars value, Industrialization (IND) in value added (% of GDP), Urbanization (UP) as total urban population, Transportation (TP) in percent of commercial service exports, Energy Consumption (EC) in kg of oil equivalent per capita and Carbon Emission (CO₂) in kiloton (kt) from 1976 to 2017

Table 1 Description and source of variables used

Variable	Abbreviation	Unit	Data source
Agricultural products export	APE	1000 US\$	FAO 2018
Industrialization	IND	Value added (% of GDP)	WDI 2018
Urbanization	UP	Actual figure of urban population	FAO 2018
Transportation	TP	% of commercial service exports	WDI 2018
Energy Consumption	EC	kg of oil equivalent per capita	WDI 2018/International Energy Agency
Carbon emission	CO ₂	Kiloton (kt)	WDI 2018/EDGAR 2020

Authors collected from World Bank (<https://databank.worldbank.org/source/world-development-indicators>), Food and Agriculture Organization (<http://www.fao.org/faostat/en/#data/QC>), International Energy Agency ([https://www.iea.org/data-and-statistics?country=PAKISTAN&fuel=Energy%20consumption&indicator=Total%20final%20consumption%20\(TFC\)%20by%20source](https://www.iea.org/data-and-statistics?country=PAKISTAN&fuel=Energy%20consumption&indicator=Total%20final%20consumption%20(TFC)%20by%20source)), and Electronic Data Gathering, Analysis, and Retrieval EDGAR (<https://edgar.jrc.ec.europa.eu/overview.php?v=booklet2018>)

Fig. 2 Time trends of study variables

in Pakistan. From Fig. 2, it is clear that agricultural products export were continuously increasing but since 2007 it returns to a diminishing trend, while urbanization and carbon emission are gradually increasing with decreasing in transportation and industrialization. Generally, we can see that carbon

emission also needs to return in a diminishing trend with industrialization and transportation because both sectors are consumers of non-renewable energies.

The schematic diagram of the study is presented in Fig. 3. The descriptive statistics of the study variables

Fig. 3 Schematic diagram of the study

Table 2 Descriptive statistics of desired variables

Tests	LnAPE	LnIND	LnUP	LnTP	LnEC	Ln CO ₂
Mean	5.977	1.326	7.602	1.699	2.618	4.914
Median	5.899	1.331	7.619	1.706	2.638	4.976
Maximum	6.492	1.407	7.879	1.829	2.719	5.295
Minimum	5.580	1.254	7.264	1.379	2.476	4.359
Std. dev	0.270	0.031	0.183	0.089	0.073	0.277
Skewness	0.297	0.123	−0.225	−1.577	−0.559	−0.478
Kurtosis	1.856	3.817	1.847	6.259	2.053	2.030
Jarque-Bera	2.907	1.276	2.679	36.007	3.754	3.243
Probability	0.234	0.528	0.262	0.000	0.153	0.197
No. of observations	42	42	42	42	42	42

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measured in natural logarithms are summarized in Table 2.

Model description

In order to examine the relationship between dependent variable agricultural products export (APE) and independent variables industrialization (IND), urbanization (URB), transportation (TP), energy consumption (EC), and carbon emission (CO₂), the framework is established based on the autoregressive distributed lag (ARDL) model employed by (Rehman et al. 2020a) (Eq. 1). The autoregressive distributed lag bounding test method was introduced by Pesaran et al. (2001) to check the existence of cointegration, while also used to check the short and long-run equilibrium among the selected time-series data. The ARDL has an edge over a simple cointegration approach due to the flexible stationary properties of the variables and can analyze both at the level, first difference, and even mutually cointegrated (Pesaran and Shin 1998). The ARDL method can deliver consistent and efficient evidence by a small sample (Haug 2002). At the same time, it can estimate the coefficients of one variable on another in the short- and long run; it can also estimate the effect of the endogenous explanatory variable (Pesaran and Shin 1998; Pesaran et al. 2001).

$$APE_t = f(IND_t, URB_t, TP_t, EC_t, CO_{2t}) \quad (1)$$

where APE stands for agricultural products export, IND for industrialization, URB for urbanization, TP represents transportation, EC represents energy consumption, and CO₂ stands for carbon emission.

After assuming the linear relationship between the study variables, the model is specified as Eq. 2:

$$APE_t = \varepsilon_0 + \varepsilon_1 IND_t + \varepsilon_2 URB_t + \varepsilon_3 TP_t + \varepsilon_4 EC_t + \varepsilon_5 CO_{2t} + v_t \quad (2)$$

By employing the logarithm to Eq. 2, the model follows a log-linear form and can be expressed as follows in Eq. 3:

$$LnAPE_t = \alpha_0 + \alpha_1 LnIND_t + \alpha_2 LnURB_t + \alpha_3 LnTP_t + \alpha_4 LnEC_t + \alpha_5 LnCO_{2t} + \varepsilon_t, \quad (3)$$

where Ln denotes the logarithmic form, t acquires the time period, and ε is the error term. Meanwhile, the coefficients α_i (where $i = 1, 2, 3, 4, 5$) represent long-run elasticity.

Methodology

Stationary test

The variables were checked for the stationary properties by employing Augmented Dickey-Fuller (ADF) tests (Dickey and Fuller 1979) and Phillips-Perron (PP) tests (Phillips and Perron 1988), whether the time-series data of the selected study variables are stationary at level/ first difference or both. The checking of stationarity between two variables was introduced by Granger (1981). The null hypothesis is there is a unit root of non-stationary at the level for ADF and PP unit root tests, whereas the alternative hypothesis reveals that there is no unit root of stationary. The ADF and PP unit-roots are expressed in the following Eqs. 4 and 5:

$$\Delta U_t = \delta_0 + \delta_1 U_{t-1} + \sum_{j=k}^l d_j \Delta U_{t-j} + Q_t, \quad (4)$$

where U_t represents time-series, Δ is the first difference operator, δ_0 denotes constant, dependent variable optimum numbers of lags are represented by l , and the pure white noise error term is represented by Q_t , while the PP unit root test is expressed in Eq. (5):

$$\Delta U_t = \delta + l * U_{t-1} + Q_t. \quad (5)$$

Both unit root tests are grounded upon t-statistics.

ARDL bounds testing method, short and long-run estimates

The ARDL model was introduced by (Pesaran and Pesaran 1997; Pesaran and Shin 1998; Pesaran et al. 2001), and it was employed to examine the relationships among the time-series data variables, i.e., APE, IND, URB, TP, EC, and CO₂ in the long-run. The ARDL model is expressed as follows in Eq. (6):

$$\begin{aligned} \Delta \text{LnAPE}_t = & \alpha_0 + \alpha_1 \sum_{i=1}^k \Delta \text{LnAPE}_{t-i} + \alpha_2 \sum_{i=1}^k \Delta \text{LnIND}_{t-i} \\ & + \alpha_3 \sum_{i=1}^k \Delta \text{LnURB}_{t-i} + \alpha_4 \sum_{i=1}^k \Delta \text{LnTP}_{t-i} \\ & + \alpha_5 \sum_{i=1}^k \Delta \text{LnEC}_{t-i} + \alpha_6 \sum_{i=1}^k \Delta \text{LnCO}_{2t-i} \\ & + \alpha_7 \text{LnAPE}_{t-1} + \alpha_8 \text{LnIND}_{t-1} + \alpha_9 \text{LnURB}_{t-1} \\ & + \alpha_{10} \text{LnTP}_{t-1} + \alpha_{11} \text{LnEC}_{t-1} + \alpha_{12} \text{LnCO}_{2t-1} + \varepsilon_t \end{aligned} \quad (6)$$

where ε is the white noise error term and Δ entitles the difference operator. The summation sign represents error correction dynamics and α_0 symbolizes constant. The second part of Eq. (6) represents the long-run association. For the identification of the optimal lag of each series and model, the AIC, SC, and HQC were applied. This technique is frequently utilized by enormous researchers with different objectives and variables (Khan et al. 2020c; Koondhar et al. 2020; Liu and Bae 2018; Ohlan 2013; Rehman et al. 2019c). The long-run association in the study time-series data can be shown by Wald (F statistics) assessment for the combined significance of assessments of the lagged level of the study time-series data (Pesaran et al. 2001). While examining the long-run association among study variables, if the calculated value of the F test surpasses the upper critical bound (UCB) value, the null hypothesis of no cointegration between variables is rejected. If the computed value of the F test falls among the lower and upper critical bounds, the result is inconclusive. While if the computed value of the F test is less than the lower critical bound, the null hypothesis of no cointegration among variables is accepted. In addition, if there exists a long-run association between study variables, at that point, the long-run coefficient is assessed. Equation 7 for the long-run estimation model is as follows:

$$\begin{aligned} \Delta \text{LnAPE}_t = & \lambda_0 + \lambda_1 \sum_{i=1}^k \Delta \text{LnAPE}_{t-i} + \lambda_2 \sum_{i=1}^k \Delta \text{LnIND}_{t-i} \\ & + \lambda_3 \sum_{i=1}^k \Delta \text{LnUP}_{t-i} + \lambda_4 \sum_{i=1}^k \Delta \text{LnTP}_{t-i} \\ & + \lambda_5 \sum_{i=1}^k \Delta \text{LnEC}_{t-i} + \lambda_6 \sum_{i=1}^k \Delta \text{LnCO}_{2t-i} + \varepsilon_t \end{aligned} \quad (7)$$

Furthermore, if found evidence of the long-run relationship between the study variables, then the short-run model will be

projected. The estimated short-run model is projected as the following Eq. 8:

$$\begin{aligned} \Delta \text{LnAPE}_t = & \varsigma_0 + \varsigma_1 \sum_{i=1}^k \Delta \text{LnAPE}_{t-i} + \varsigma_2 \sum_{i=1}^k \Delta \text{LnIND}_{t-i} \\ & + \varsigma_3 \sum_{i=1}^k \Delta \text{LnUP}_{t-i} + \varsigma_4 \sum_{i=1}^k \Delta \text{LnTP}_{t-i} \\ & + \varsigma_5 \sum_{i=1}^k \Delta \text{LnEC}_{t-i} + \varsigma_6 \sum_{i=1}^k \Delta \text{LnCO}_{2t-i} \\ & + \eta \text{ECT}_{t-1} + \varepsilon_t. \end{aligned} \quad (8)$$

where the coefficient of the ECT is represented by η in the estimated model.

Results and discussion

Unit root test

The empirical results of Augmented Dickey-Fuller (ADF) and Phillip-Perron (PP) unit root tests are stated in Table 3. These tests were recognized by Dickey and Fuller (1979) and Phillips and Perron (1988) for the first time to inspect the stationary properties of variables. According to the ADF and PP tests, outcomes represent that some of the study variables are stationary at level $I(0)$ and some of them are stationary at the first difference $I(1)$. This confirms the application of the ARDL model.

ARDL cointegration test and parameters estimates

In the preference to other criteria, the Schwarz Information Criteria (SIC) is commonly used as they express better specifications (Pesaran et al. 1999). This study employs SIC criteria to decide the best fitting lag for the ARDL model to overcome the sample's limitation.

Furthermore, the ARDL-bound testing method is used to define the cointegration association between LnAPE and other variables (LnIND, LnUP, LnTP, LnEC, and LnCO₂). The values of critical bounds for both of the samples of the small and large sizes are presumed by Pesaran et al. (2001). According to the Pesaran critical value table, if the F -state value is below the lower bound, then the alternative hypothesis will be rejected and the null hypothesis will be accepted. The null hypothesis will be rejected when the F -state value surpasses the upper bound critical value, and if the F -state value is between the upper bound and lower bound, then there is bias in results. The results are expressed in Table 4 and indicate that the value of F -statistics is more than the upper bound critical value, and it is significant at 1% level, which provides evidence that there is cointegration between the agricultural production export, industrialization, urbanization, transportation, energy consumption, and carbon emission in Pakistan. In emerging market and developing economies,

Table 3 Results of the unit root test

Variables	Level		1st difference		Outcome
	Intercept	Trend and intercept	Intercept	Trend and intercept	
Augmented Dickey fuller					
LnIND	−2.558	−2.701	−7.574***	−7.767***	I(1)
LnUP	−3.583**	−2.093	−1.333	−2.976	I(0)
LnTP	0.991	0.271	−6.153***	−6.947***	I(1)
LnEC	−2.390	0.478	−5.769***	−7.082***	I(1)
Ln CO ₂	−3.625***	−1.414	−5.584***	−7.244***	I(0)/I(1)
LnAPE	−0.830	−3.869**	−7.437***	−7.329***	I(0)/I(1)
Phillip-Perron					
LnIND	−2.434	−2.571	−7.690***	−9.149***	I(1)
LnUP	−22.816***	−1.565	−0.530	−2.281	I(0)
LnTP	1.420	0.271	−6.190***	−6.947***	I(1)
LnEC	−2.366	1.244	−5.852***	−7.095***	I(1)
Ln CO ₂	−4.000**	−1.414	−5.882***	−7.239***	I(0)/I(1)
LnAPE	−1.258	−3.912**	−9.910***	−9.731***	I(0)/I(1)

Automatic lag length selection based on SIC

***Acquired null hypothesis rejected at 1% level, **reject the null hypothesis at 5% significant level, results in author calculation by using Eviews 9

increasing in energy consumption and globalization financial development causes to increase in carbon emission (Öztürk and Le 2020). These results postulate that the null hypothesis of no cointegration between study variables is rejected, and the alternative hypothesis of cointegration between study variables is selected. The estimated results confirm the existence of five long-term associations between agricultural products export and other study variables (LnIND, LnUP, LnTP, LnEC, and LnCO₂) in Pakistan.

Long-run and short-run analysis based on ARDL

The outcomes of the ARDL long-and short-run elasticity between agricultural products export and other study variables (LnIND, LnUP, LnTP, LnEC, and LnCO₂) are presented in Table 5. These outcomes provide evidence of the existence of

long- and short-run correlation among the study time-series variables. In the case of long-run association energy consumption related to agricultural products export is positive at a 1% significance level (coefficient 19.889), which reveals that a 1% increase in energy consumption may increase agricultural products export by 19.9%. Energy consumption has a positive effect because of the efficient crop cultivation and getting higher production needs to adopt modern agricultural technologies, and those technologies consume more energy (Ahmed and Zeshan 2014). In Turkey, agricultural production decreased due to climate factors such as rainfall, CO₂ emission, and high temperature (Öztürk et al. 2020b). Similar results were also found by Raeeni et al. (2019) from Iran using time-series data from 1967 to 2015 estimate Johansen-Juselius cointegration and granger causality.

The coefficients of urbanization, transportation, and carbon emission are negative and show a significant impact on agricultural products export. These results postulate that a 1% increase in urbanization, transportation, and carbon emission significantly decreases agricultural products export by 11.8%, 6.3%, and 13% respectively. This empirical evidence for carbon emission is the same as Khan et al. (2020b). The results show that an increase in carbon emission brings climate change and results in the decline of Pakistan's agricultural products export, these results are contrary to the studies of Khan et al. (2019), Ali et al. (2019), and Khan and Tahir (2018). While the evidence of transportation is different from Tabasam and Ismail (2019), who found that improvement in the transportation infrastructure in Pakistan significantly and positively affects agricultural trade in Pakistan. However, our

Table 4 Results of ARDL bounding test for cointegration

Test statistic	Value	<i>K</i>
F-statistic	5.558134	5
Critical value bounds		
Significance	<i>I</i> (0) bound	<i>I</i> (1) bound
10%	2.08	3
5%	2.39	3.38
2.5%	2.7	3.73
1%	3.06	4.15

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Table 5 Long- and short-run estimates analyzed by ARDL

Variables	Coefficient	Std. Error	T-test	P value
Long-run association				
C	−38.691	12.347	−3.134	0.009*
LnIND	−1.673	2.134	−0.784	0.449
LnUP	−11.760	2.446	4.808	0.000***
LnTP	−6.263	1.460	−4.289	0.001***
LnEC	19.889	3.882	5.123	0.000***
Ln CO ₂	−13.023	2.154	−6.046	0.000***
Short-run association				
D(LnAPE(−1))	2.318	0.380	6.100	0.000***
D(LnAPE(−2))	1.714	0.286	6.001	0.000***
D(LnAPE(−3))	0.322	0.127	2.544	0.027
D(LnIND)	0.145	0.520	0.278	0.785
D(LnIND(−1))	2.056	0.478	4.301	0.001***
D(LnIND(−2))	1.569	0.561	2.795	0.017
D(LnIND(−3))	2.765	0.528	5.239	0.000***
D(LnUP)	−124.897	64.582	−1.934	0.079
D(LnUP(−1))	−110.585	98.075	−1.128	0.283
D(LnUP(−2))	−302.866	96.465	−3.140	0.009**
D(LnTP)	−1.681	0.364	−4.619	0.000***
D(LnTP(−1))	3.187	0.458	6.955	0.000***
D(LnTP(−2))	1.326	0.310	4.276	0.001***
D(LnEC)	6.335	1.308	4.842	0.000***
D(LnEC(−1))	−13.270	1.999	−6.638	0.000***
D(LnEC(−2))	−6.651	1.434	−4.639	0.000***
D(Ln CO ₂)	−9.027	1.044	−8.651	0.000***
D(Ln CO ₂ (−1))	4.982	1.305	3.817	0.002**
D(Ln CO ₂ (−2))	7.838	1.447	5.416	0.000***
ECT(−1)	−3.681	0.474	−7.754	0.000***
R ²	0.907	Akaike information criteria	−2.865	
Adjust R ²	0.799	Schwarz criterion	−1.960	
Log-likelihood	75.428	Hannan-Quinn criteria	−2.543	
Prob	0.000	D.W	2.029	
Normality	11.869	LM test	0.745	
Heteroskedasticity	0.443			

***Acquired null hypothesis rejected at 1% level, **reject the null hypothesis as 5% significant level, results in author calculation by using Eviews 9

study does not claim to have a significant effect of industrialization on agricultural products export.

In addition, the short-run estimations are also expressed in the middle portion of Table 5. Industrialization, transportation, and energy consumption exert a positive and significant impact on agricultural products export at a 1% significance level. In the short-run, a 1% increase in industrialization, transportation, and energy consumption increases agricultural products export by 2.8%, 3.2%, and 6.3% respectively. Ahmed and Zeshan (2014) and Tabasam and Ismail (2019) concluded that energy consumption has a positive and significant short-

run correlation with transportation. The carbon emission coefficient is negative and is significant at the 1% level, which means that a 1% increase in carbon emissions will decrease agricultural products export by 9% in the short run. This empirical evidence is previously proofed by Rehman et al. (2020a), while urbanization is found to be negatively associated at a 5% level of significance. It shows that an increase of 1% in the urban population will decrease agricultural products export by 302.9% in the short-run. It is obvious because of the increase in urbanization resulting in decreasing agricultural arable land, an increase in population as well and subsequently increasing food security issues due to the rise in food demand and causing a negative effect on agricultural products exports (Hashmi 2011; Wu et al. 2018). The interesting thing we can see is that in Table 5, almost all the variables are significant at 1% level both in long-run and short-run nexus because at the first stage, we selected a total of nine variables; then, we remove three variable due to having non-significant results, and in this study, we just focused on highly significant variables. These six variables were selected based on variables importance projection. In addition, the error correction term (ECT-1) shows the speed of adjustment from short- to long-run and is significant at a 1% level with a negative coefficient sign that rejects the null hypothesis and accepted alternative hypothesis. The last part of Table 5 indicates the outcomes of some important statistical tests. According to the statistics, the model passes other major tests including normality, heteroskedasticity, R^2 , and Durbin-Watson (DW).

Granger causality test

The granger causality test provides estimations to check the directional causal connections between the study variables. The results of the Granger causality test are presented in Table 6, and it shows that there is a unidirectional causal connection between industrialization to transportation. This means that industrialization granger causes transportation, i.e., LnIND affects LnTP, while LnTP does not affect LnIND. In addition, results also show unidirectional Granger causality running from energy consumption towards the agricultural products export, industrialization, and transportation, i.e., LnEC granger causes LnAPE, LnIND, and LnTP while none of the study variables granger causes LnEC.

Robustness test

To check the stability and validity of the ARDL model test, the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUMSQ) tests developed by Brown et al. (1975) were utilized. The figure represents that in both CUSUM and CUSUMSQ tests, the plot falls within the significance limit at the 5% level (Fig. 4). This represents that all the parameters used in the model estimation are stable over the

Table 6 Granger causality tests

Dependent variables	Independent variables					
	LnAPE	LnIND	LnUP	LnTP	LnEC	LnCO ₂
LnAPE	–	0.66105	0.44781	1.34479	3.02413**	2.06719
LnIND	0.33620	–	0.74110	0.17917	2.64850**	1.17982
LnUP	0.92546	0.84031	–	1.38575	1.09466	1.59651
LnTP	0.85199	5.40460***	0.90920	–	2.52408*	0.60877
LnEC	1.47862	0.62214	0.20885	1.59218	–	1.53519
Ln CO ₂	0.72789	0.80836	0.33670	0.58960	1.11925	–

***Acquired null hypothesis rejected at 1% level, **reject the null hypothesis as 5% significant level, results in author calculation by using Eviews 9

sample period. Therefore, the parameters and models used in the study are efficient and reliable. This type of robustness test

was previously applied by different researchers with different parameters for examining the reliability of the study model

Fig. 4 Robustness test results analyzed by Eviews 9

(Ali et al. 2020; Baz et al. 2019; Koondhar et al. 2020; Koondhar et al. 2018; Öztürk et al. 2020a; Rehman et al. 2019a; Wang et al. 2019).

Conclusion and policy implications

In this study, we examined the causal linkages between industrialization, urbanization, transportation, energy consumption, carbon emission, and agricultural products export in Pakistan over the time period of 1976 to 2017. Annual time-series data was gathered from FAO, WDI, IEA, and Electronic Data Gathering, Analysis, and Retrieval. The ADF and PP unit-root tests confirmed that all the variables are stationary at the level and first difference. In addition, the results of the ARDL bounding test shows that there are cointegration linkages among the study variables at a 1% significance level. The long-run estimates connote that a 1% increase in energy consumption causes increases in agricultural products export by 19.9%, while a 1% increase in urbanization, transportation, and carbon emission decreasing agricultural products export by 11.8%, 6.3%, and 13% respectively. In the short run, a 1% increase in industrialization, transportation, and energy consumption leads to an increase in agricultural products export by 2.8%, 3.2%, and 6.3% respectively. An increase in carbon emission by 1% decreases agricultural products export by 9%, and short-run agricultural products export decrease due to an increase in urban population.

Furthermore, the Granger causality test estimation proofed the evidence of unidirectional causality running from between industrialization, transportation, energy consumption, towards the agricultural products export. In addition, CUSUM and CUSUMSQ tests disclosed the stability, reliability, stationarity, and effectiveness of the particular model.

Policy implications were measured based on the above empirical results. The government of Pakistan should manage the land reforms and build the high stories building rather than occupy more agricultural land for urbanization which resulting to decrease in arable land. Also, the Pakistani government should subsidize those industries which are making value-added agricultural products, processing, and provide marketing channels, also need to urge them for consuming renewable energy for low carbon emission to the environment. For increasing the export at the international level, the government of Pakistan should organize exhibitions and introduce the agricultural products of Pakistan for finding new international markets. Increasing agricultural products export not only will contribute to the economic development of Pakistan but also will provide the opportunity to many other non-agricultural countries to import Pakistani agricultural products in order to combat the food demand. Also, it will increase the value and recognition of Pakistani agricultural products to many other countries.

Nomenclature ARDL, autoregressive distributed lag; ADF, Augmented Dickey-Fuller; PP, Phillip-Perron; CUSUM, cumulative sum; CUSUMSQ, cumulative sum of square; UCB, upper critical bound; D.W, Durbin Watson; ECT, error correction term; AIC, Akaike's information criterion; SC, Schwarz criterion; HQC, Hannan-Quinn criterion; GDP, gross domestic product; GOP, government of Pakistan; WDI, World Development Indicators; FAO, Food and Agriculture Organization

Author contribution All authors made significant contributions to the study conception and design. Data curation and methodology were performed by Z.A.K and M.A.K. Z.A.K, M.A.K, and I.K did formal analysis and software. Z.A.K wrote the original draft. Review and editing were performed by Z.A.K, M.A.K, and U.A. Supervision by L.T.

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Data availability The data used in the study for analysis can be found on the web links from the repositories of World Bank (<https://databank.worldbank.org/source/world-development-indicators>), Food and Agriculture Organization (<http://www.fao.org/faostat/en/#data/QC>), International Energy Agency ([https://www.iea.org/data-and-statistics?country=PAKISTAN&fuel=Energy%20consumption&indicator=Total%20final%20consumption%20\(TFC\)%20by%20source](https://www.iea.org/data-and-statistics?country=PAKISTAN&fuel=Energy%20consumption&indicator=Total%20final%20consumption%20(TFC)%20by%20source)), and Electronic Data Gathering, Analysis, and Retrieval EDGAR (<https://edgar.jrc.ec.europa.eu/overview.php?v=booklet2018>).

Declarations

Ethical approval and consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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