Linking CO₂ Emissions and Crop Production: Empirical Evidence from South Asian Countries

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Linking CO2 emissions and crop production: empirical evidence from South Asian countries

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Abstract

It is need of the hour to investigate the impacts of climate parameters on agricultural production in a developing region of South Asia. Therefore, this work attempts to explore the climatic indicators on agricultural production for selected South Asian countries over the annual data of 1961-2016. This study estimates the impacts of rainfall, temperature, rural population, land under cereal production, and CO₂ emissions on agricultural production. For empirical analysis, we applied second-generation unit root tests. After examining the order of integration of time series, we check for the co-integration among the variables. Before the co-integration test, we check for cross-section dependence among the variables. CD and LM tests confirm the existence of cross-section dependence. Afterward, we apply Westerlud co-integration test to confirm the strong association among the variables. Further, we applied two methods for long-run coefficients of independent variables. DOLS and FMOLS tests were applied to cross-check the findings. Our findings show that rural population and rainfall are negatively associated with agricultural production. Moreover, temperature, land area under cereal production, and CO₂ emissions are positively associated with agricultural production. Our findings shed light on some important policy implications for South Asian countries.

KEYWORDS: South Asia; Crop Production; FMOLS; DOLS

Introduction

In recent years, climate change has become a central argument in many public and political talks at the local and global levels. Climate change has become a major problem for both developed and developing economies. Many nations have faced the severe effects of change in climate on several economic sectors especially agriculture (Chhogyel et al., 2020; Warsame et al., 2021). Agricultural activities exist in almost every country and permit the farmers to grow their crops with feasible inputs (Sarkodie et al., 2019). The effect of climate change and extreme meteorological conditions such as unusual rainfall patterns and temperature changes are more on the agricultural sector than other sectors (Ahsan et al., 2020).

In recent years, climate change has become a worldwide problem which attracted the attention of international organizations, government, and non-government organizations to address the issues of climate change internationally (Eregha et al., 2014). In developing economies, the climate change impact has been extensively marked, particularly in the countries that are based on agriculture than advanced economies. This could be due to the developed nation's capability to counter the change in climate issues abruptly and to alleviate its adverse effects. On the contrary, developing countries like Pakistan mainly depend upon the agricultural zone as it imparts towards the employment and export earnings substantially. The developing economies are at more risk of climate change issues due to their more dependency on the agricultural sector (Nhamo et al., 2019).

Pakistan's agricultural sector plays the role of the pillar of the country's economy since it adds to total export earnings of approximately 70% (Hussain, 2017). Wheat, sugarcane, maize, cotton, and rice are few main crops of the country. Long-term climatic parameters and short-term weather changes affect agricultural productivity (Shannon and Motha, 2015). Pakistan was positioned 8th in 2015 and is considered as one of the major countries urges to change in climate

(Kreft and Eckstein, 2013). In Pakistan, the floods of 2010 and 2014 have badly destructed millions of rural households. In Pakistan, a major issue for the Pakistani government is that climate dangers arise continuously but sufficient use of previous development of strategies and cost-effective types of equipment are yet insufficient (Qasim et al., 2015). Rice and wheat are major crops for the people of South Asia, both these crops are affected by high temperatures, yet rice is not susceptible as wheat (Fahad and Wang, 2018). Lesser production of wheat and rice crops are likely to be anticipated not only in the south Asian countries but also throughout the whole globe due to the change in climate (Lobell and Gourdji, 2012).

Recent studies have used econometric models such as co-integration and ordinary least square method to examine the climate change agriculture production. In Malaysia Murad et al., (2010) examined the impact of climate change totally on agriculture and CO₂ emissions by the use of econometric technique namely ordinary least square. They reported that the per capita increase in CO₂ emissions significantly enhances the production of an agricultural index. (Chandio et al., 2020) analyzed the climatic influence on the production of agriculture using ARDL and Johansen co-integration methods over China. They analyzed that agricultural output was significantly enhanced by CO₂ emissions in both the long-run and short-run. Furthermore, they described the detrimental effect of rainfalls and temperatures on crop yields in the long run. However, no such study has examined the impact of climate parameters such as rainfall, average temperature, and CO₂ emissions on the production of crops in south Asia by using econometric technique namely, ARDL for the period 1961-2016.

Materials and methods

Study area

South Asia is considered ecologically the world's most densely occupied and populated region having a population of ~1.891 billion i.e. the ¼ of the global population. The land surface area of South Asia is ~ 5.2 million km² that is 3.5% of the world and 11.71% of the Asian continent. As per the South Asian Association for Regional Cooperation (SAARC), eight countries lies in South Asia i.e. Pakistan, Bangladesh, India, Afghanistan, Bhutan, Sri Lanka, Nepal, and Maldives (Unep, 2009). Figure one shows the spatial map of South Asian countries.

Figure 1. Representing countries of South Asia (Pakistan, Bangladesh, India, Afghanistan, Bhutan, Sri Lanka, Nepal, and the Maldives)

Datasets

The time series throughout 1961-2016 has been taken for the study area i.e. Pakistan, Bangladesh, India, Afghanistan, Bhutan, Sri Lanka, Nepal, and Maldives. as shown in figure 1. The datasets have been taken from the world bank and the Organization of Islamic Cooperation Statistical, Economic, Social Research and Training Centers of Islamic Countries (SESRIC). the parameters incorporated in the study are: CO₂ Emissions (ECO₂), Land Under Cereal Production (LCUP), Rural Population (RP), Crop Production Index (CPI), Precipitation Data (PD), Temperature (TEMP)

The detailed description is given in Table 1.

Table 1: Description of the parameters taken throughout 1961-2016 for South Asia

Parameters		Code	Description	Units	Source
Carbon dioxide Emissions		ECO ₂	CO ₂ emissions	metric tons per capita	World Bank
Land Under Cereal Production		LCUP	Land under cereal production	hectares	SESRIC
Rural Population		RP	Rural population	% of total population	SESRIC
Crop Production Index		CPI	Crop production index	2004-2006 = 100	SESRIC
Precipitation Data		PD	Avg. annual precipitation	mm	World Bank
Temperature		TEMP	Avg. annual temp	°C	World Bank

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124 **Methodology**

125 To define the specific impact of climatic parameters on crop production, this research
126 consists following equation,

$$127 \quad CPI_t = f(RP_t, TEMP_t, PD_t, LCUP_t, ECO_{2t}) \quad (1)$$

128 Here is CPI is crop Index, rural population is indicated as RP, temperature's indicator is
129 TEMP, PD indicates rainfall, and LCUP is land under cereal production and ECO2 is carbon
130 emissions.

131 In the single multivariate framework, the relationship between different variables will
132 consider in equations. All the data transform to natural logarithms. The reason for this
133 conversion is given by (Bekhet and Othman 2017). They mention that it is important to convert
134 data to natural logarithms to minimize the possible presence of heteroscedasticity. They also
135 clear that to minimize the sharpness of data log-linear model show more solid finding than the
136 simple model (Shahbaz 2013). The empirical model for this study is specified as follows:

$$137 \quad \ln CPI_{it} = \beta_0 + \beta_1 \ln RP_{it} + \beta_2 \ln TEMP_{it} + \beta_3 \ln PD_{it} + \beta_4 \ln LCUP_{it} + \beta_5 \ln ECO_{2it} \\ 138 \quad + \varepsilon_{it} \quad (3)$$

139 In equation (3), β_0 denotes the constant term; $\beta_1, \beta_2, \beta_3$, and β_4 represent the long-run elasticities
140 of independent variables respectively; the coefficient of the interaction term between public debt
141 and the renewable energy consumption is represented as β_5 ; term error is shown as ε_{it} ; and $t =$
142 1, 2, ..., n

A six-stage analysis has been conducted to investigate the long-run relationship between the variables. Priorly, the panel data has been analyzed to check that either the data is cross-sectional dependent or not. This test provides worthy results and is used to avoid any partial results.

So, the LM test by Breusch and Pagan (1980), and the CD test by Pesaran and M.H. (2004) have been used in this study. Following are the equations of these tests:

$$LM = T \sum_{i=1}^{n-1} \sum_{j=i+1}^n \partial_{ij}^t$$

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{n-1} \sum_{j=i+1}^n \partial_{ij}^t \right)$$

Where the number of cross-sections is denoted as N and time are denoted by T. The paired relationship of error is denoted as ∂_{ij}^t . To determine the slope, a slope homogeneity test has been conducted. If homogeneity is present among the panel data non reliable results can be produced (Le and Ozturk, 2020). Following equations of $\tilde{\Delta}$ and $\tilde{\Delta}_{adj}$ are for Slope homogeneity tests:

$$\tilde{\Delta} = \sqrt{N} \left(\frac{N^{-1}\tilde{S} - K}{\sqrt{2K}} \right)$$

$$\tilde{\Delta}_{adj} = \sqrt{N} \left(\frac{N^{-1}\tilde{S} - E(\tilde{Z}_{iT})}{\sqrt{var(\tilde{Z}_{iT})}} \right)$$

Where $E(\tilde{Z}_{iT}) = K$ and $var(\tilde{Z}_{iT}) = 2K(T-K-1)/(T+1)$. Following is the equation is of modified test of $\tilde{S}$.

$$\tilde{S} = \sum_{i=1}^n (\hat{\gamma}_i - \tilde{\gamma}_{WFE}) \frac{Y_i' M_T X_i}{\tilde{\sigma}_i^2} (\hat{\gamma}_i - \tilde{\gamma}_{WFE})$$

For individual units, the value of pooled OLS is denoted by $\hat{\gamma}_i$ while weighted pool eliminator is denoted by $\tilde{\gamma}_{WFE}$ and identity matrix is represented by M_T .

The subsequent step is to observe the order of integration among the variables. Because imitated results can be produced in the presence of time series among unit-roots. To monitor variables' stationary properties two types of unit root test has been conducted. Therefore, a set of first-generation unit root tests (Levin et al., 2002; Pesaran et al., 2001) and a set of second-generation unit root tests are implicated in the data. To apply the simple regression of ordinary least square (OLS) the result of the unit root test should be the order of integration at level $I(0)$. However, it will become compulsory to go for co-integration examination if the variables are found to be co-integrated at first difference. Here, Westerlund and Edgerton, (2007) test have been applied, instead of the co-integration techniques of (Johansen and Juselius, 1990; Kao, 1999; Pedroni, 1999). The cross-section dependence among the time series has been examined in Westerlund and Edgerton, (2007) test.

In the next step, the long-run coefficients have been estimated. For that FMOLS and DOLS, techniques have been applied, and the following are their equations:

$$\hat{\gamma}_{FMOLS} = \left[N^{-1} \sum_{i=1}^N \left(\sum_{t=1}^t u_{it} - \bar{u}_i \right)^2 \right]^{-1} \times \left[\left(\sum_{t=1}^T u_{it} - \bar{u}_i \right) \hat{s}_{it} - T \hat{\Delta}_{\epsilon\mu} \right]$$

$$\hat{\gamma}_{DOLS} = \left[N^{-1} \sum_{i=1}^N \left(\sum_{t=1}^T c_{it} c'_{it} \right)^{-1} \left(\sum_{t=1}^T c_{it} c'_{it} \right) \right]$$

To remove the endogeneity and the autocorrelations these tests have been generally used. To expose the causality among the variables a test has been conducted.

This test is efficient because it removes the problem of CS in the data.

Results and discussion

Table 2: LLC and IPS unit root tests

Variable	Im, Pesaran, Shin		Levin-Lin-Chu unit root test	
	At level	1 st difference	At Level	1 st difference
$\ln CPI_t$	-0.43	-3.61***	-4.72***	-8.80***
$\ln RP_t$	1.56	-1.66**	3.33	-13.90***
$\ln TEMP_t$	0.26	-4.27***	0.49	-3.02***
$\ln PD_t$	-1.93**	-0.36	-5.65***	-1.40**
$\ln LCUP_t$	1.51	-4.19***	-0.41	-11.14***
$\ln ECO_{2t}$	1.45	-1.48**	-13.04***	-12.60***

Table 3: CADF and CIPS unit root tests

Variable	CIPS test		CADF test	
	At level	1 st difference	At Level	1 st difference
$\ln CPI_t$	-2.50	-5.40***	-1.87	-2.53**
$\ln RP_t$	-3.31***	-5.72***	-2.76	-4.52***
$\ln TEMP_t$	-3.62**	-5.40***	-3.51***	-4.84***
$\ln PD_t$	-1.41	-2.46**	-3.12**	-2.35*
$\ln LCUP_t$	0.47	-2.53**	-1.45	-4.22**
$\ln ECO_{2t}$	-1.51	-4.66***	-2.77	-3.66***

Table 4: Cross-section dependence test

	lnCPI	lnRP	lnTEMP	lnPD	lnCUP	lnECO ₂
LM test	119.62*** (0.00)	160.92*** (0.00)	97.37*** (0.00)	4.83*** (0.02)	57.28*** (0.00)	93.20*** (0.00)
CD test	26.56*** (0.00)	34.49*** (0.00)	27.12*** (0.00)	3.87*** (0.00)	3.09*** (0.00)	20.39*** (0.00)

Table 5: shows Slope homogeneity

Tests	LM stats	Prob
$\tilde{\Delta}$	2.37***	0.01
$\Delta_{adj}^{\sim}$	2.89***	0.00

Table 6: Westerlund test

stats	values	Z-value	Prob	Robust prob
G_a	-3.61***	4.33	1.00	0.00
G_t	-1.22	4.04	1.00	0.80
P_a	-2.78***	3.40	1.00	0.00
P_t	-1.70	4.17	1.00	0.55

197 **Table 7: DOLS and FMOLS test results**

Variables	DOLS	prob	FMOLS	Prob
$\ln RP_t$	-0.19***	0.00	-0.20***	0.00
$\ln TEMP_t$	2.49***	0.00	0.17***	0.00
$\ln PD_t$	-0.40	0.61	-0.10	0.56
$\ln LCUP_t$	0.86***	0.00	0.46**	0.07
$\ln ECO_{2t}$	0.17***	0.00	0.27***	0.00

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199 To cross-check the results two sets of unit root tests have been applied. Tables 2 and 3 show the

200 result of the unit root test (first and second generation). As the variables are integrated at a level

201 and first difference, their results, therefore, indicate that they have a mixed order of integration.

202 After that, a cross-sectional dependence of panel data has been examined and for that matter, LM

203 and CD test has been applied. Owing to geographical association these variables are

204 interdependent as shown in table 4. Further in table 5 slope homogeneity has been examined and

205 it shows that there is no problem with it. A strong linkage between the data series has been

206 examined by the Westerlund co-integration test as shown in table 6. After co-integration, the

207 short and long-run analysis has been conducted. For authenticated results, DOLS and FMOLS

208 techniques have been commonly used. The results of these techniques have been shown in table

209 7. It was found that RP and PD are the major causes that lower crop production. These

210 conclusions are linked with (Gavin). The effect of PD is inconsequential. On the other hand, CO₂

211 emissions cause an increase in crop production. Interestingly, CO₂ emissions are increasing crop

212 production, which means that air pollution is increasing crop production in South Asian

213 economies. This finding is not similar to the findings of (Warsame et al., 2021). Increasing

temperature is useful for more crop production in South Asian countries. This finding is not similar to (Warsame et al., 2021). Increasing temperature is useful for agricultural production in South Asian countries. We can say that increasing temperature is no hurdle in the way of agricultural production. Moreover, land under cereal production also increasing crop production at a 1% level. These results are similar to (Warsame et al., 2021). The findings of FMOS are consistent with the findings of DOLS estimation. More land area utilizes for agricultural production will add to more agricultural production.

Our findings show that climate and non-climate factors are determinants of crop production in South Asian countries.

Conclusion and Policy implications

It is need of the hour to investigate the impacts of climate parameters on agricultural production in a developing region of South Asia. Therefore, this work attempts to explore the climatic indicators on agricultural production for selected South Asian countries over the annual data of 1961-2016. This study estimates the impacts of rainfall, temperature, rural population, land under cereal production, and CO₂ emissions on agricultural production. For empirical analysis, we applied second-generation unit root tests. After examining the order of integration of time series, we check for the co-integration among the variables. Before the co-integration test, we check for cross-section dependence among the variables. CD and LM tests confirm the existence of cross-section dependence. Afterward, we apply Westerlud co-integration test to confirm the strong association among the variables. Further, we applied two methods for long-run coefficients of independent variables. FMOLS and DOLS tests were applied to cross-check the findings.

Our findings show that rural population and rainfall are negatively associated with agricultural production. Moreover, temperature, land area under cereal production, and CO₂ emissions are positively associated with agricultural production. Our findings shed light on some important policy implications for South Asian countries. First of all, the rural population is lowering agricultural-related GDP, which means that there is a need to contain the spread of the rural population to lower its negative impacts on agricultural GDP. In this regard, governments need to introduce such policies by which land area cannot be covered by urban settlements in South Asian countries. The natural greenery of rural areas should not be harmed by the increasing rural population. Rainfall has negative impacts on crop production, which means that these countries are facing more rainfall due to drastic climatic variability. A high rate of rainfall causes floods in vast areas, which effect adverse impacts on crops. Land area under cereal production and temperature helps increase crop production. Interestingly, CO₂ emissions are not a hurdle in the way of crop production in South Asian countries.

Apart from the contribution of this study, there are some limitations, which can be covered by future studies. We applied data for South Asian countries to find their co-integration. Future studies can use satellite-based data for other developed countries to explore more in-depth policy instruments.

Declarations

Ethical Approval

Not required

Consent to Publish

Not Applicable

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Consent to Participate

All authors participate in this research.

Authors Contributions

Zia ul Haq conceptualizes the work. Usman Mehmood conducted analysis and wrote the manuscript. Ayesha azhar wrote the manuscript. Fazzal Qayyum make maps and wrote the description. Hassan Nawaz wrote the manuscript. Salman Tariq wrote the manuscript.

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Competing Interests

Not Required

Availability of data and materials

Not required

References

Breusch, T.S., Pagan, A.R., 1980. The Lagrange Multiplier Test and its Applications to Model

280 Specification in Econometrics. *Rev. Econ. Stud.* 47, 239–253.
 281 <https://doi.org/10.2307/2297111>

282 Chandio, A.A., Rehman, A., Rauf, A., 2020. Short and long-run impacts of climate change on
 283 agriculture : an empirical evidence from China 12, 201–221.
 284 <https://doi.org/10.1108/IJCCSM-05-2019-0026>

285 Chhogyel, N., Hasan, L.K.Y.B.K., 2020. Perception of farmers on climate change and its impacts
 286 on agriculture across various altitudinal zones of Bhutan Himalayas. *Int. J. Environ. Sci.*
 287 *Technol.* <https://doi.org/10.1007/s13762-020-02662-8>

288 Eregha, P.B., Babatolu, J.S., Akinnubi, R.T., 2014. Climate change and crop production in
 289 Nigeria: An error correction modelling approach. *Int. J. Energy Econ. Policy* 4, 297–311.

290 Fahad, S., Wang, J., 2018. Farmers’ risk perception, vulnerability, and adaptation to climate
 291 change in rural Pakistan. *Land use policy* 79, 301–309.
 292 <https://doi.org/10.1016/j.landusepol.2018.08.018>

293 Hussain, M.I., 2017. PAKISTAN ’ S MAJOR EXPORTS AND IMPORTS ROLE AND
 294 IMPORTANCE FOR Andamios . *Revista de Investigación* ISSN : 1870-0063 de Cillia ,
 295 Rudolf ; Reisigl , Martin ; Woddak , Ruth LA CONSTRUCCIÓN DISCURSIVA DE
 296 IDENTIDADES NACIONALES México México Universidad Autóno.

297 Johansen, S., Juselius, K., 1990. Maximum likelihood estimation and inference on co-
 298 integration. *Oxf. Bull. Econ. Stat.*

299 Kao, C., 1999. Spurious regression and residual-based tests for cointegration in panel data. *J.*
 300 *Econom.* 90, 1–44. [https://doi.org/10.1016/S0304-4076\(98\)00023-2](https://doi.org/10.1016/S0304-4076(98)00023-2)

301 Kreft, S., Eckstein, D., 2013. Global Climate Risk Index 2014: Who suffers most from extreme
 302 weather events? Weather-related loss events in 2012 and 1993 to 2012, Germanwatch
 303 Briefing Paper.

304 Le, H.P., Ozturk, I., 2020. The impacts of globalization, financial development, government
 305 expenditures, and institutional quality on CO 2 emissions in the presence of environmental
 306 Kuznets curve. *Environ. Sci. Pollut. Res.* 2020 2718 27, 22680–22697.
 307 <https://doi.org/10.1007/s11356-020-08812-2>

308 Levin, A., Lin, C.-F., James Chu, C.-S., 2002. Unit root tests in panel data: asymptotic and finite-
 309 sample properties. *J. Econom.* 108, 1–24. [https://doi.org/10.1016/S0304-4076\(01\)00098-7](https://doi.org/10.1016/S0304-4076(01)00098-7)

310 Lobell, D.B., Gourdji, S.M., 2012. The influence of climate change on global crop productivity.
 311 *Plant Physiol.* 160, 1686–1697. <https://doi.org/10.1104/pp.112.208298>

312 Markou, M., Moraiti, C.A., Stylianou, A., Papadavid, G., 2020. Addressing climate change
 313 impacts on agriculture: Adaptation measures for six crops in Cyprus. *Atmosphere (Basel).*
 314 11, 1–15. <https://doi.org/10.3390/ATMOS11050483>

315 Murad, W., Islam Molla, R., Bin Mokhtar, M., Raquib, A., 2010. Climate change and
 316 agricultural growth: An examination of the link in Malaysia. *Int. J. Clim. Chang. Strateg.*
 317 *Manag.* <https://doi.org/10.1108/17568691011089927>

- Nhamo, L., Matchaya, G., Mabhaudhi, T., Nhlengethwa, S., Nhemachena, C., Mpandeli, S., 2019. Cereal production trends under climate change: Impacts and adaptation strategies in Southern Africa. *Agric.* 9, 1–16. <https://doi.org/10.3390/agriculture9020030>
- Pedroni, P., 1999. Critical Values for Cointegration Tests in Heterogeneous Panels with Multiple Regressors. *Oxf. Bull. Econ. Stat.* 61, 653–670. <https://doi.org/10.1111/1468-0084.0610s1653>
- Pesaran, M.H., 2004. ‘General Diagnostic Tests for Cross Section Dependence in Panels.’ Cambridge Work. Pap. Econ.
- Pesaran, M.H., Shin, Y., Smith, R.J., 2001. Bounds testing approaches to the analysis of level relationships. *J. Appl. Econom.* 16, 289–326. <https://doi.org/10.1002/jae.616>
- Qasim, S., Nawaz Khan, A., Prasad Shrestha, R., Qasim, M., 2015. Risk perception of the people in the flood prone Khyber Pukhthunkhwa province of Pakistan. *Int. J. Disaster Risk Reduct.* 14, 373–378. <https://doi.org/10.1016/j.ijdrr.2015.09.001>
- Sarkodie, S.A., Ntiamoah, E.B., Li, D., 2019. Panel heterogeneous distribution analysis of trade and modernized agriculture on CO2 emissions: The role of renewable and fossil fuel energy consumption. *Nat. Resour. Forum* 43, 135–153. <https://doi.org/10.1111/1477-8947.12183>
- Shannon, H.D., Motha, R.P., 2015. Managing weather and climate risks to agriculture in North America, Central America and the Caribbean. *Weather Clim. Extrem.* 10, 50–56. <https://doi.org/10.1016/j.wace.2015.10.006>
- Unep, 2009. South Asia Environment Outlook 2009.
- Warsame, A.A., Sheik-Ali, I.A., Ali, A.O., Sarkodie, S.A., 2021. Climate change and crop production nexus in Somalia: an empirical evidence from ARDL technique. *Environ. Sci. Pollut. Res.* <https://doi.org/10.1007/s11356-020-11739-3>
- Westerlund, J., Edgerton, D.L., 2007. A panel bootstrap cointegration test. *Econ. Lett.* 97, 185–190. <https://doi.org/10.1016/j.econlet.2007.03.003>