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RETRACTED: Green finance, green energy, and green revolution: An impulse response function of food security in developing economies

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RETRACTED

Recently, it has been observed that fossil fuel utilization increased to manage the issue of food insecurity; however, it has increased the risk of environmental degradation and land availability. Therefore, the role of a farmer is to ensure food security (FS). With the assistance of the green revolution (GR), green finance (GF) and green energy have increased manifold. For this purpose, the current study utilized a time-series dataset between 2071 and 2019 to evaluate the relationship between green finance, green energy, and the green revolution with food security. This objective has been considered with modern econometric methods, including the Johansen cointegration model and impulse response. As a result, the Johansen model affirmed cointegration between the green revolution, green finance, and green energy with food security. According to the results, food security will rise by 0.17%, 2.05%, 0.006%, and 0.023%, with a 1% increase in fossil fuel utilization, green finance, improved seeds, and water availability, respectively. Furthermore, based on the diagnostic statistics, the Johansen model's credibility, stability, and reliability were corrected. In light of these findings and the impulse response function, all relevant factors will favor future food security. Finally, this study suggested that the public and commercial sectors should invest significantly in R&D to produce organic chemicals and agricultural methods that preserve soil fertility and reduce environmental degradation.

KEYWORDS
green revolution, green finance, fossil fuel, impulse response function, food security

Introduction

An economy's socioeconomic development and economic progress would be impossible without the agricultural contribution (Singh et al., 2016; Ali et al., 2020). Agriculture is still the primary source of income and provides raw materials for many other businesses in the economy, making it the most critical industry. However, in emerging nations such as Pakistan and India, agriculture employs a considerable portion of the workforce. People in rural and urban regions also rely on agriculture (Abe et al., 2009). For example, Pakistan, the world's fifth-most populous nation, has a greater need for food. Therefore, agriculture has become the backbone of the economy (GOP, 2020). Pakistan's agricultural output has fallen compared to other emerging countries in the recent decade. However, it has stayed steady and has increased at a respectable annual rate of 5.1% due to technical developments, subsidies, and agricultural research (Xie and Huang, 2021; Baharudin and Waked, 2021; Liu et al., 2021). On the contrary, there are many obstacles such as lack of credit, water shortage, lack of seeds and fertilizers, pesticides, low fertility of the land, power deficiencies, and oil price volatility in the agricultural flourishment (Admassie and Abebaw, (2021).

A growing global population is also putting a tremendous strain on agricultural resources. Therefore, it has become a significant economic cash generator (export). To put it another way, the agriculture part of the gross domestic product has decreased, accounting for just 19.3% of GDP (GOP, 2020). Nevertheless, agriculture has much more potential to be realized with the most recent technological innovations. Agriculture supplies raw materials (Micari et al., 2020), which employs the most significant number and provides the majority of industries. Poverty reduction is made possible by its expansion, which may also enhance the socioeconomic standing of a large proportion of the population (GOP, 2020). In addition, agriculture helps build other sectors by supplying raw materials and creating the demand for industrial goods in non-agricultural areas.

According to the most recent figures, wheat contributes 8.7% of Pakistan's agricultural output and 1.7% of the country's gross domestic product. Perishable and non-perishable foods both saw a rise in production due to green revolution (Harwood, 2020). High-yielding varieties are the primary components of the green revolution (GR) (Konappa et al., 2021; Alimkulova and Aitmukhanbetova, 2020; Reddy et al., 2021). Pakistan embraced GR in the late 1960s. Later, higher-yielding seeds were demonstrated to affect crop productivity (Ullah and Khan, 2020). As a result, farmers ensure food security (FS) with improved crops, fertilizers, and pesticides (Ullah and Khan, 2020), indirectly lowering the income disparities (Kutkowska et al., 2019).

The study's objective is to examine the GR's dynamic impact on FS, which is either affected by the availability of green finance (GF) or green energy. In addition, do fossil fuel prices affect FS? Is there a link between the exhibition and economic development due to a lack of fertilizer and pesticides in the presence of big dataset and components of GR? For the most part, this article is composed of a review of related literature, data analysis, methodological considerations, findings, discussion, and recommendations.

Literature review

The agricultural economy of Pakistan is well-known across the world. A significant amount of study has been done on various econometric approaches and variables to have a solid foundation. Wheat, cotton, and rice have favored economic development (Lestari, 2019). Many factors contribute to the success of a farmland's agricultural production, including water availability, the availability of fertilizers, pesticides, and GF (Bader et al., 2021; Bindraban et al., 2020; Geisseler et al., 2022). FS is influenced by the availability of education, productivity, farm sizes, and fertilizers (Diallo et al., 2020). Fertilizers favorably influence farmers' labor and revenue and are the solution for soil deficiency. Without fertilizers, a significant increase in FS is unachievable (Manimaran et al., 2019).

However, developing nations such as Pakistan, India, Sri Lanka, and Bangladesh have limited access to GF (Khan and January 2018). A little limited or low access to GF, it is hard to modernize agriculture in rural areas (Kalykova, 2020). Agriculture-related technologies and self-sufficiency are essential to achieving economic growth (Atef, 2019; Tashi et al., 2022). A significant access to the GF boosts production (Gonçalves et al., 2021; Bashir et al., 2019). The peasantry can be modernized if cheap and simple GR is available (Khanal and Omobitan, 2020). However, farmers are reluctant to take out loans because the disbursement procedure is cumbersome and time-consuming (Supardi and Saerang, 2018). Therefore, they purchase their inputs on the open market at double prices (Ye et al., 2018).

Access to GF or its availability enhances the employment of agricultural equipment, seeds, chemicals, and water availability to farmers (Azimy et al., 2020; Tan et al., 2021; Biye et al., 2018; Adebayo et al., 2020; Yakasai, 2010). With GF, better crop verity, and more effective herbicides and fertilizers, peasants can increase their agricultural production (Huang et al., 2020; Tyapkina et al., 2021). Small farmers' access to financing is critical in supporting macroeconomic development that is driven by agriculture, and small-scale wheat farmers in Pakistan produce wheat for survival because grain consumption is so high (Tesfaye et al., 2021; Merrey and Lefore, 2019; Wambua et al., 2021).

The agricultural industry is expected to develop by 4.40% in 2021–2022, both the projected growth rate of 3.5% and the previous year's growth rate of 3.48%. The increased availability of certified seeds, insecticides, and GF and the favorable government regulations contribute to agricultural development. From 2021 to 2022, crops are expected to expand at a 6.58% annual rate, compared to a 5.96% growth rate in the previous year (GOP 2020). Wheat production is reduced when insufficient water is available for its cultivation (Han et al., 2018; Khan et al., 2019; Jiang et al., 2020; Xiong et al., 2020; Bouzidi and Campana, 2021; Hoppert and Einfalt, 2021). Micro-water shed management may assist in dealing with such water shortages (Korai et al., 2021; Chakraborty et al., 2022; Wang et al., 2020). Water intensity per cropped area may be increased using this strategy, which results in an increased total production (Niu et al., 2021; Zhou et al., 2021; Kurzweil et al., 2021; Gao et al., 2021).

Consequently, we can say that many researchers utilized factors that resemble each other. Moreover, wheat production never deals with the GR and FS, especially in the developing economies in the context of fossil fuel energy consumption. Therefore, the current study took the initiative to discuss the issue of FS concerning fossil fuel consumption and the GR in the developing economy. Thus, the main objective of this study is to determine the participation of the GR, GF, and green energy along with fossil fuel utilization to ensure FS. Time-series data were arranged (1971–2019) to accomplish the objective. Modern econometric methods such as Johnson cointegration, ARDL bound, and impulse response were employed to enlist the influence of the GR, GF, and green energy, ensuring FS. The available research in this area of work utilized odd or even factors to evaluate their influence on the GR on FS; however, no comprehensive work can be found in this regard. Therefore, the current study employed all the possible factors which can influence or highlight the issue of FS. Furthermore, due to the latest dataset and modern evaluation methods of econometrics, this work provides a fresh perspective on this field.

Data and methodology

This study uses yearly data from 1971 to 2019 to examine the impact of the GR's components on economic development, focusing on Pakistan. This research gathered data from the World Development Indicators (WDI) and several Pakistan Economy Survey (PES) issues. A proxy for FS was total wheat output, whereas a representative for land use was area utilization for wheat cultivation. The use of fossil fuels as a renewable energy source and GF as a proxy for the availability of financial resources improved seed as a proxy for seed technology (SD_{tech}) and fertilizer use for FS. Agricultural water availability is used as a proxy for irrigation when evaluating FS regarding pesticide consumption. Finally, sustainable development is a proxy for gross domestic product. Therefore, Table 1 elaborates the profile regarding source, unit and abbreviations used in the study.

The response variable was the total amount of wheat produced, calculated in thousand metric tons (TMT). At the same time, external factors included the total area under cultivation for the wheat crop (million hectares: MH), the number of fossil fuels used (thousand litters: TL), and the total amount of GF (billion rupees: BR), improved seeds (thousand tons), fertilizers (thousand tons), pesticides (TL), irrigation (million acre-feet), and the gross domestic product (current US$).

Extending a difference in a model developed by Perron (1989), the break is calculated by Zivot and Andrews (1992). As a result, Zivot and Andrews (1992) called their model a sequential trend break model. There is a predefined break in

TABLE 1 Variables profile, measurement, and source.

Factors	Full description and measurement unit	Source
FS	Total wheat production (TMT)	PES (2020)
LU	Area for the wheat crop (MH)	PES (2020)
FF	Fossil fuel utilization (TL)	WDI (2020)
FRA	Total green finance (BR)	WDI (2020)
$SD_{(tech)}$	Improved seeds (thousand tons)	PES (2020)
$FC_{(FS)}$	Fertilizers (thousand tons)	PES (2020)
$PC_{(FS)}$	Pesticides (TL)	PES (2020)
$WA_{(FS)}$	Irrigation (million acres-feet)	PES (2020)
$G_{(c\$)}$	Gross domestic product (current US$)	WDI (2020)

Perron (1989), whereas there is an approximated break in Zivot and Andrews (1992). The one-sided statistic was minimized by selecting TB (breakpoint). The following is an example of an endogenous structural break in the Zivot–Andrews model:

$$Z_t = \eta + \beta Z_{t-1} + \lambda_t + \theta FU_t + \sum_{m=1}^{h} c_m Z_{t-m} + \epsilon_t \quad (1)$$

$$Z_t = \eta + \beta Z_{t-1} + \delta_t + \gamma FT_t + \sum_{m=1}^{g} c_m Z_{t-m} + e_t, \quad (2)$$

$$Z_t = \eta + \beta Z_{t-1} + \delta_t + \theta FU_t + \gamma FT_t + \sum_{m=1}^{g} c_m Z_{t-m} + e_t \quad (3)$$

They applied the work of Pesaran et al. (2001) to analyze the variables' short and long association with the assistance of the ARDL bound approach. The contributing affiliation of food security with explanatory variables is stated as follows:

$$FS = f\left(LU, FF, FRA, SD_{(tech)}, FC_{(FS)}, PC_{(FS)}, WA_{(FS)}, G_{(c)}\right). \quad (4)$$

According to Shahbaz et al. (2012), the logarithmic form is more trustworthy and effective at this stage. However, log-linear appearance springs better results with manageable variance related to the simple description as it lessens perceptiveness in the time series data. The study will also make use of the vector error correction approach for short-term links between the aforementioned parameters. The following equations are related to VECM and are represented as follows:

$$\begin{aligned} \ln FS = {} & \alpha_0 + \alpha_1 \ln LU + \alpha_2 \ln FF + \alpha_3 \ln FRA + \alpha_4 \ln SD_{(tech)} \\ & + \alpha_5 \ln FC_{(FS)} + \alpha_6 \ln WA_{(FS)} + \alpha_7 \ln PC_{(FS)} + \alpha_8 \ln G + \eta_t \end{aligned}, \quad (5)$$

where α_0 shows the intercept and α_1, α_2, α_3, α_4, α_5, α_6, α_7, and α_8 are the parameters. We accept a positive relationship between LU, FF, FRA, $SD_{(tech)}$, $FC_{(FS)}$, $PC_{(FS)}$, $WA_{(FS)}$, and $GDP_{(c\$)}$ with FS. Therefore, the vector error correction (VECM) can be reported:

TABLE 2 Augmented Dicker Fuller Unit Root.

FS	LU	FF	FRA	SD	FC	PC	WA	G
-8.41*(0.00)								
	-8.58* (0.00)							
		-6.06* (0.00)						
			-5.56* (0.00)					
				-7.16* (0.00)				
					-7.74* (0.00)			
						-5.93* (0.00)		
							-12.96* (0.00)	
								-7.65* (0.00)

Note: All time series are stationary at first difference

$$\begin{aligned}\Delta \ln(\mathrm{FS})_t = \beta_0 &+ \sum_{i=1}^{k}\beta_{1i}\Delta\ln(\mathrm{FS})_{t-i} + \sum_{l=1}^{l}\beta_{2l}\Delta\ln(\mathrm{LU})_{t-l}\\ &+ \sum_{m=1}^{m}\beta_{3m}\Delta\ln(\mathrm{FF})_{t-m} + \sum_{n=1}^{n}\beta_{4n}\Delta\ln(\mathrm{FRA})_{t-n}\\ &+ \sum_{p=1}^{p}\beta_{5p}\Delta\ln(\mathrm{SD_{tech}})_{t-p} + \sum_{k=1}^{k}\beta_{6k}\Delta\ln(\mathrm{FC_{FS}})_{t-k}\\ &+ \sum_{r=1}^{r}\beta_{7r}\Delta\ln(\mathrm{WA_{FS}})_{t-r} + \sum_{g=1}^{g}\beta_{8g}\Delta\ln(\mathrm{PC_{FS}})_{t-g}\\ &+ \sum_{s=1}^{s}\beta_{9s}\Delta\ln(\mathrm{G_{c\$}})_{t-s} + \alpha_1\Delta\ln(\mathrm{FS})_{t-i} + \alpha_2\Delta\ln(\mathrm{LU})\\ &+ \alpha_3\ln(\mathrm{FF})_{t-1} + \alpha_4\ln(\mathrm{FRA})_{t-1} + \alpha_5\ln(\mathrm{SD_{tech}})_{t-1}\\ &+ \alpha_6\ln(\mathrm{FC_{FS}})_{t-1} + \alpha_7\ln(\mathrm{WA_{FS}})_{t-1} + \alpha_8\ln(\mathrm{PC_{FS}})_{t-1} \end{aligned} \tag{6}$$

.

Johansen test (1991) is used to determine the long-term relationship between the Food security and green finance, land utilization, components of green revolution and gross domestic product. However, this test consists of two parts: the trace value and the maximum eigenvalue. Therefore, we have a long-term affiliation between food security and explanatory variables in Pesaran et al. (2001) and Narayan (2004). The F-statistic is more than the upper critical at a 5% significance level with the null hypothesis (i.e., no cointegration between FS with independent variables and *vice versa*). The results are inconvincible if the F-state lies within the upper and lower bound.

Autoregressive conditional heteroskedasticity (ARCH) analyzes past volatility to predict future volatility. A more realistic representation of market volatility is provided by ARCH modeling, which is often employed in the financial sector to quantify risk. It is clear from the ARCH modeling that times of extreme volatility are followed by even more high volatility and *vice versa*.

Because of volatility or variation clusters, investors need to assess the risk associated with keeping an asset over years or decades. Economist Robert F. Engle III first proposed the ARCH model in the 1980s:

$$\begin{aligned} W_t &= b + \mu_t\\ \mu_t &\sim \text{iid } N(0, \sigma_t^2)\\ \sigma_t^2 &= b_0 \end{aligned} \tag{7}$$

Regression models may be tested using the Ramsey RESET test in economics. For example, is a non-linear combination of fitted values helpful in describing a variable that is not linear?

$$\begin{aligned} S &= \alpha_1 + \sum_{j=2}^{1}\alpha_j R_j + \epsilon\\ Y &= a_1 + \sum_{j=2}^{n} a_j R_j \end{aligned} \tag{8}$$

The Breusch–Godfrey test may detect autocorrelation up to any predefined order *p*, unlike the Durbin–Watson Test. A more comprehensive range of regressors may be accommodated by it as well:

$$\begin{aligned} Y_t &= \delta_1 + \sum_{k=2}^{p}\delta_j R_{jt} + \epsilon_t\\ \epsilon_t &= \lambda_1 + \sum_{k=2}^{p}\lambda_j R_{jt} + \rho\epsilon_{t-1} \end{aligned} \tag{9}$$

The Jarque-Berra (JB) test assesses normalcy. The JB test confirms normality. Other normality tests fail when n is big (Shapiro–Wilk is not reliable with n above 2,000); hence, it is used for large datasets. Data are compared to a normal distribution to determine if they are skewed or kurtosis-free:

$$JB_{stat} = n\left[\frac{S^2}{6} + \frac{(K-3)^2}{24}\right]. \tag{10}$$

Individual coefficient estimates provide little information on the system's response to a shock because all variables in a VAR model are interrelated. Instead, impulse responses (IR) help comprehend a model's dynamic behavior. The moving average representation is the starting point for every implicit response function in a linear VAR model:

$$\lambda_i = \sum_{j=1}^{i}\lambda_{i-j}A_j, \tag{11}$$

10.3389/fenvs.2022.982785

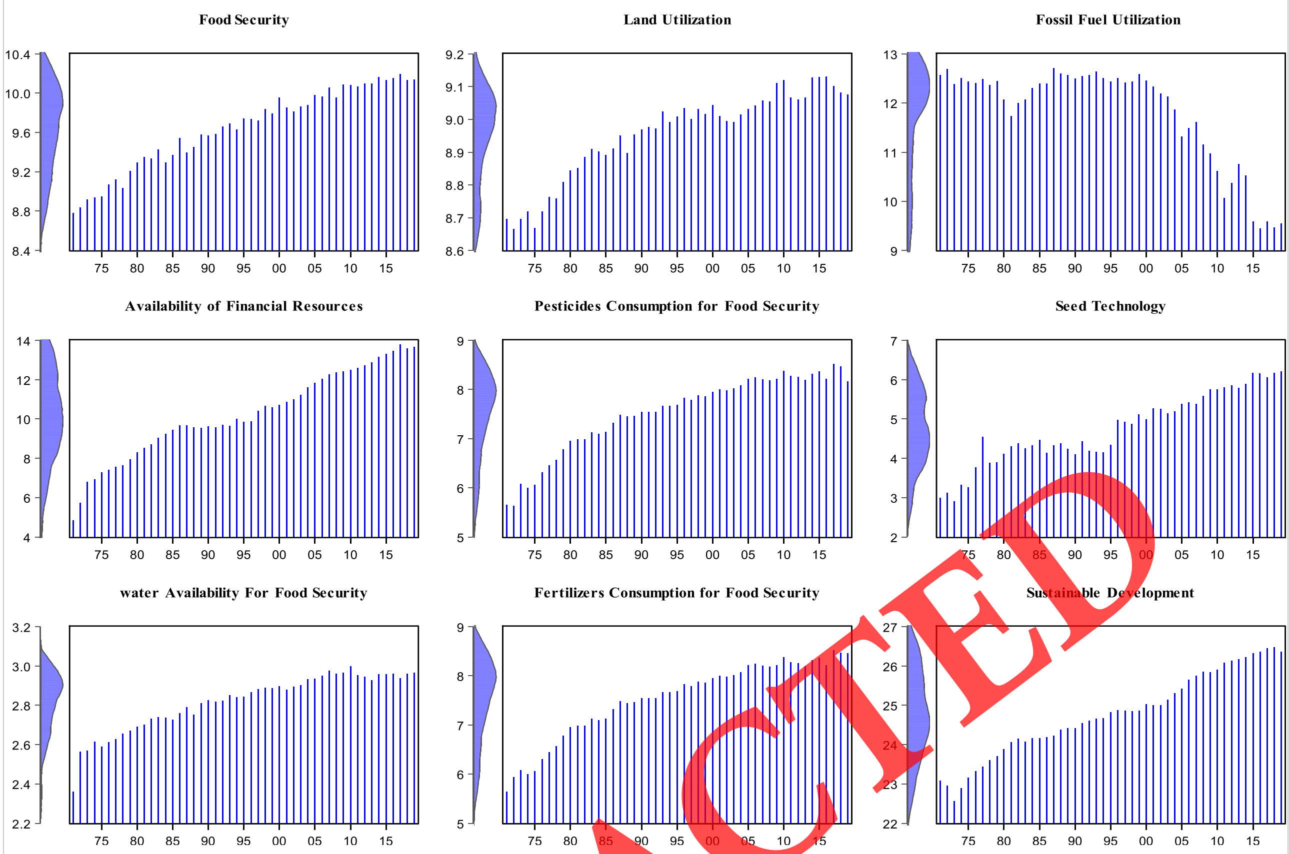

FIGURE 1
Periodic tendency of variables.

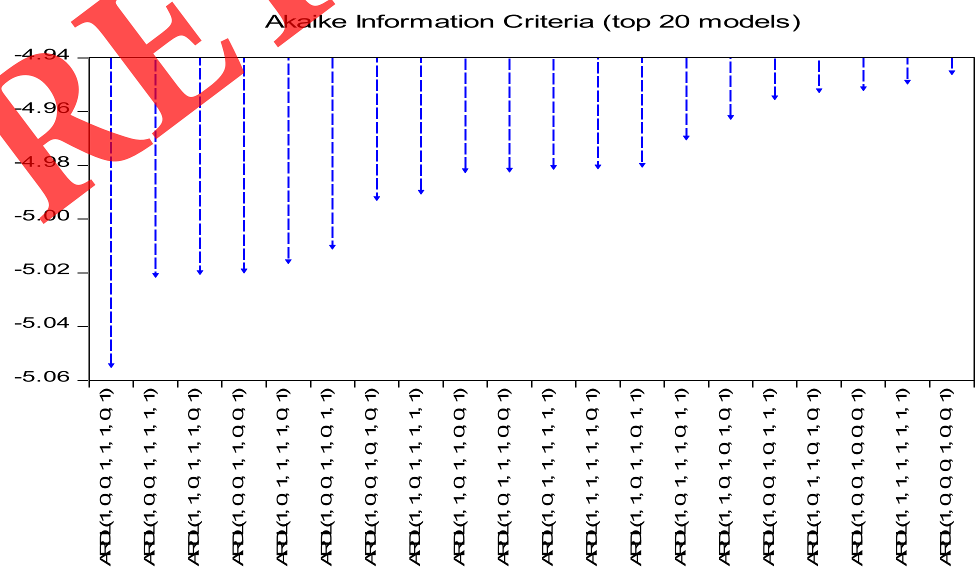

FIGURE 2
Top 20 models based on the ARDL estimation of the AIC criterion.

FIGURE 3
Residuals of each variable.

where λ_i = Ik and Aj = 0 for j > p, while "Δ" for lag order and "K" for some endogenous variables. $IRF(\lambda, \delta) = \vartheta y_{t+h}/\vartheta_{\epsilon_t}$ shows a shock εt = δat time *t* impacts a system at time *t* + *h*:

$$IRF(\lambda, \delta, \tau_{t-1}) = E[y_{t+h} I\eta_t = \delta, \eta_{t+h} = 0, \tau_{t-1}] - E[y_{t+h} I\eta_t = 0, \eta_{t+h} = 0, \tau_{t-1}]. \quad (12)$$

There is no need to estimate equations for dependent variables that are not the subject of the inquiry, and the local projection approach provides a more parsimonious specification. In addition, variables on both sides of a VAR equation need not have the same form:

$$y_{t+h} = I_{t-1}\left[\beta_{c,j} + \Phi_{c,j}(L)y_{t-1} + \alpha_{c,j}shock_t\right] + (1 - I_{t-1})\left[\alpha_{b,j} + \Phi_{b,j}(L)y_{t-1} + \alpha_{b,j}shock_t\right] + linear\_trend + \mu_{t+j}. \quad (13)$$

Empirical results

The outcomes are based on the empirical analysis presented in Table 2. We start with the unit root test based on Augmented Dicky Fuller (ADF) here. As the name suggests, the ADF measures the zero and constant variance of all variables.

Meanwhile, Figure 1 shows how each variable's historical trend has changed. The mean and covariance of stationary series remain constant across time. Mean-reverting suggests that the series is susceptible to a short-term shock. Finally, the unit root identification in the context of structural fractures is examined. Research into structural fractures and unit roots has yielded a variety of unit root tests. There are many tests based on the number of breaks in the data and whether there is a pattern presence, however, the Zivot Andrew structural beak test is presented in Table 3.

Table 3 shows that despite catching one endogenously determined gap in the data, the Zivot–Andrews test found that all the variables tested have a unit root.

TABLE 3 Structural beak test.

Variables	Year	t-stat.	Prob.
FS	1993	−4.21	0.013
LU	1979	−4.1	0.031
FF	2008	−2.86	0.018
FRA	1989	−5.46	0.002
$SD_{(tech)}$	1986	−4.84	0.002
$FC_{(FS)}$	1986	−3.61	0.005
$PC_{(FS)}$	1989	−2.87	0.004
$WA_{(FS)}$	2011	−4.07	0.001
$G_{(c\$)}$	1983	−4.43	0.008

TABLE 4 ARDL bound test.

Test statistic	Value	Sig. (%)	I (0)	I (1)
			Asymptotic: n = 1,000	
F-statistic	7.338	10	1.95	3.06
K	8	5	2.22	3.39
		2.50	2.48	3.70
		1	2.73	4.10

Source: author(s) calculation.

Furthermore, this work utilized the ARDL bound test presented in Table 4, introduced by Pesaran et al. (2001), to determine the short- and long-term association between FS and the LU, FF, and components of the GR (FRD, SD, FC, PC, and WA). The estimations are represented in Table 4.

The particular F-state value provided by Pesaran et al. (2001) and Narayan (2004) for ARDL bound shows that the value (7.338) is more than the upper critical bounds at a 10% significant level, k = 8. Consequently, the concept of no cointegration is rejected against the existence of cointegration. Therefore, we can say that the long-term association prevails between FS and the possible determinants of the GR.

The outcomes of the Johansen cointegration found many equilibrium relationships exist which determine the combined evolution of all the model's variables. Fortunately, as the model includes more than two variables, it is anticipated that this study may have several co-integrating vectors. Thus, there are three co-integrating vectors in the estimation, since each of their Trace statistic values is more than the 5% crucial threshold, result is presented in Table 5. In other words, these factors increase wheat production in Pakistan in the long term. In addition, other variables such as LU, FC, and PC positively influence and subsidize the FS in Pakistan. On the contrary, the FF, FRA, SD, and WA are provided in less quantity; that is why their influence is unsubstantial in the short run.

As a consequence of the findings, we can say that the normalization cointegration approach for the long run have both positive and negative influences on the GR factors of the production of food in the country. Moreover, to determine the Johansen

TABLE 5 Estimation of the VECM and Johansen Cointegration.

Variables	Coefficients	Std. Error	t stat	prob.
LU	-0.0008	-0.001	-0.763	0.001*
FF	-0.01	-0.009	-1.068	0.008*
FRA	-0.008	-0.005	-1.567	0.003*
$SD_{(tech)}$	0.004	-0.009	0.465	0.01**
$FC_{(FS)}$	-0.0004	-0.003	-0.122	0.02**
$PC_{(FS)}$	-0.007	-0.003	-2.025	0.001*
$WA_{(FS)}$	-0.01	-0.013	-0.767	0.01**
$G_{(c\$)}$	4.35	-4.1	1.054	3.9
Cointegration Eq(-)	-0.65	0.12	-3.53	0.02
Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
At most 1 *	0.759619	211.8301	159.5297	0.0000*
At most 2 *	0.609442	144.8302	125.6154	0.0020*
At most 3 *	0.558670	100.6418	95.75366	0.0221**
Maximum Eigen Values				
None *	0.891282	104.2929	58.43354	0.0000*
At most 1 *	0.759619	66.99991	52.36261	0.0009*
At most 2	0.609442	44.18839	46.23142	0.0816***
Normalized cointegrating coefficients				
LU	-2.927	-0.607		
FF	0.000	0.000		
FRA	0.054	-0.043		
$SD_{(tech)}$	0.000	0.000		
$FC_{(FS)}$	-0.528	-0.129		
$PC_{(FS)}$	-0.001	0.000		
$WA_{(FS)}$	0.265	-0.041		
$G_{(c\$)}$	0.604	-0.094		

cointegration model's constancy, vector the error correction model (VECM) is utilized and is articulated in Table 5. The period is significant at a 1% level, a negative sign that Johansen cointegration is dynamically stable in its current form. The cointegration Eq. 1 is 0.65, which means 65% disequilibrium precision yearly would produce Johansen model consistency.

Additionally, the normalization cointegration of Johansen approach are also shown in Table 5, which elaborates that all the GR determinants influence FS. Additionally, the long-run elasticities of the ARDL approach are also in Table 7, which elaborates that all the GR determinants influence FS. Furthermore, the VEC model finds out that all the factors such as land utilization, fossil fuel usage, green finance, and and components of the green revolution revoke the risk of food insecurity in the short run. Thus, the VEC model finds out that all the factors such as land utilization, fossil fuel usage, green finance, and and components of the green revolution revoke the risk of food insecurity in the short run. Furthermore, these findings are consistent with the study by Ullah et al. (2018). The result elaborates that the LU, FRA, SD, FC, PC, WA, and G

FIGURE 4
Impulse response function.

positively and significantly influence the FS in the long term, except for the oil utilization. In other words, we can say that GF influenced the total wheat production. On the contrary, improved seeds, fertilizers, and pesticides also influenced FS in the long term and significantly played their role in achieving the potential yield level. Moreover, the determinants of the GR, the availability of water to crops, also positively and significantly affect the FS in the long term in the case of Pakistan.

Furthermore, Figure 2 presents the best possible 20 ARDL models. Figure 4 denotes the top 20 best models to identify the suitable good fit and acceptable model because we have five selection criteria (i.e., LR, AIC, SBC, HQ, and adjusted R^2). However, the ARDL model constructed on AIC criteria was applied based on the most negligible AIC value (−5.05) with the ARDL model (1, 0, 0, 1, 1, 1, 0, 1) graphically. Therefore, Figure 4 is presented based on AIC selection criteria with the finest fitted ARDL approach.

To affirm the credibility and correctness of the model, we employed a series of investigative information, as displayed in Table 6. The ARCH and LM test outcomes elaborate no heteroscedasticity and serial correlation problems. According to the Ramsey RESET, the Johansen model in the existing arrangement is suitable, whereas the results of Jarque and Bera (1987) denote that the model is normally distributed. However, the residual diagnostic test results are also in the study's favor, which is presented in Figure 3.

VAR is the ideal strategy for extracting data-related information because it works with all parameters on a single axis, implying that there are no endogenous and exogenous factors. Furthermore, the VAR technique has used broad policy trials to alter the path of the parameters. Sims (1980) pioneered this method to capture the variables' relationship and change responses. When one parameter deviates from its steady state, what is the reaction of the other variables that comprise the system? The results of the VAR are shown in Table 7.

FIGURE 5
Local project function.

TABLE 6 Results of diagnostic tests.

Test type
#131413; ARCH test χ2-statistic value (0.95) df (1) *p*-value (0.03)
#131413; Ramsey RESET test F-statistic value (0.41) df (1,27) *p*-value (0.02)
#131413; Breusch–Godfrey serial correlation LM test χ2-statistic value (3.30) df (2) *p*-value (0.01)
#131413; Jarque–Bera test F-statistic value (4.14) *p*-value (0.03)

Source: author(s) calculation.

TABLE 7 Vector auto-regressive model.

	FS	LU	FF	FRA	$SD_{(tech)}$	$FC_{(FS)}$	$PC_{(FS)}$	$WA_{(FS)}$	$G_{(FS)}$
FS (−1)	0.123	−0.004	0.183	0.122	1.189	0.097	0.089	0.145	0.231
	−0.178	−0.074	−0.722	−0.415	−0.578	−0.237	−0.275	−0.052	−0.201
	[0.69]	[−0.065]	[0.253]	[0.294]	[2.055]	[0.411]	[0.323]	[2.757]	[1.145]

The outcome indicates a long-term relationship between the factors. To delve deeper, we employ the impulse response function, which comprehensively describes one variable's reaction when the other parameter in the network swings from its location. Figure 4 depicts the outcome of the autoregressive vector technique.

The results indicate that the FS, FRA, SD, FC, PC, and WA increased the FS in the long term and positively and had a significant influence on the growth rate of the nation when the FS was subjected to a standard deviation shock of possible predictors of the GR.

However, consider that the usual shock of the total wheat area is applied to all factors. In that instance, the response indicates that the change in wheat FF, FRA, SD, FC, PC, WA, and growth rate is directly influenced. When the GR components are subjected to a standard dose of fossil fuel, the resulting response shows that, except for water availability, all variables increased positively as fossil fuel use increased, resulting in a negative balance of payments. With fossil fuel utilization, the water availability increases, as well as the cost of production, reducing the profit volume for the peasant.

If the availability of GF among the peasants is increased, then peasant access to wheat production, improved seeds, pesticides, and irrigation payments are more accessible, enhancing the economy's growth rate. Moreover, with the credit, the access to fossil fuel utilization and fertilizers also increased, and peasants utilized these things more than the required quantity, which is the misutilization of the credit.

The impulse response results show that the improved seed, FS, fossil fuel utilization, fertilizers, pesticides, and growth rate of the country increased because of the enhancement in the determinants of the GR, which influenced FS. Furthermore, the outcomes show that the change in the utilization of fertilizers, pesticides, and irrigation may influence all other variables of the study positively. On the other side, the growth rate indicates that if the standard deviation shock of the growth rate is given to the FS and FRA, then the growth rate is increased. Still, fossil fuel utilization, pesticides, fertilizers, and improved seeds negatively affect the growth rate because home production is insufficient to fulfill the demand. Therefore, the country imports many of these goods to the market. That is why the gap between imports and exports increases, negatively influencing the economy and generating many other issues for developing economies.

The local project function Figure 5 elaborates that it can lessen food poverty and steer the economy toward more sustainable growth by using land and fossil fuels and developing seed technology and water resources.

Discussion

Economists are interested in investigating the connection between financial resource availability, fossil fuels, and elements of the GR. For the country's food supply to keep pace with demand, additional land was planted, and new knowledge and technology were employed. Pesticides, fertilizers, and irrigation are all essential components of improved seeds. Increasing pressure on the industrial sector results in more work prospects for farmers to meet these demands. Therefore, it will have a favorable impact on the company's development. Water reservoirs must be increased, though, to irrigate farmland. In addition, it may aid in generating additional electricity, which in turn aids in the expansion of the industry.

Pakistan adopted the GR in the 1960s. In contrast, new inputs were utilized in Pakistan over the same period to achieve a high output level. According to many historians and experts, the most important components of the GR were seeds, insecticides, fertilizers, and irrigation through tube wells. To boost Pakistan's agricultural economy, the government has instituted many projects. This method has a significant impact on Pakistan's agricultural output. Hamit–Haggar's (2012) findings for Canada, Marrero's (2010) results for the European Union, Nasir and Rehman's (2011) findings for Pakistan, Kanjilal and Ghosh's (2013) findings for India, and Ullah's (2020) findings for Pakistan are all supported by these results. The agricultural industry is constantly stressed to meet the country's growing need for food and feed its people. Every year, more land is being used for agriculture for this purpose. Chemical fertilizers that are more effective and have a more significant impact on productivity are readily accessible. Peasants formerly resisted using high-yield seeds, but today they are embracing them. There has been a rise in the use of fossil fuels, and peasants are now using solar panels to water their fields. The provision of loans to peasants is critical to the economy's success. Under Pakistan's many agricultural regions, the government has begun to offer tractors to the peasantry in highly favorable circumstances.

The study has sudden limitations as well. This work is limited to a single developing country due to data availability constrain. Thus, it could be a good edition in the literature and policy perspective if we can apply it to other regions, for example, the South Asian region. Furthermore, the panel vector autoregressive (PVAR) model can be adopted because this method can deal with cross-sectional dimensions.

Conclusion and suggestions

There is much strain on Pakistan's administration because of its rising population. Increasing agricultural output is one way to achieve this goal. In this perspective, Pakistan's agriculture sector has gained too much attention and is referred to be the "green revolution" in Pakistan's history. However, much resource exhaustion and overexploitation came with this transformation. We used time-series data from 1971 to 2019 to estimate the influence of the GR, GF, and fossil fuels to ensure FS.

We made use of a variety of contemporary econometric tools to achieve the goal. First, the Johansen technique was used to assess the long-term connection between endogenous and exogenous factors. Additionally, the bound test method we used revealed that the long-term link between endogenous and exogenous emerged. Moreover, the Johansen cointegration suggest that GF, GR, green energy, and fossil fuel utilization significantly contribute to FS.

Consequently, implicit but stimulating policy suggestions appear. We believe that the green course is an expensive technology. Poor farmers cannot afford and acquire newly developed technologies, simultaneously looking for GF. Getting more GF means the usage of affluent technology.

Throughout the research, several concepts are put forward. First, environmental degradation and pollution are often attributed to industrial activity. Therefore, the industrial and agricultural sectors are to be blamed for environmental degradation. Bird species have been decimated due to the widespread use of chemical fertilizers. Repeated cultivation operations diminish the soil's fertility, and even the soil becomes aperture due to the heavy application of fertilizers. Soil percolation occurs when the soil's ability to retain water decreases due to exposure to the Sun. Moreover, components of the GR are costly.

In Pakistan, peasants are involved in substantial forming. They cannot afford the costly modern technologies and expensive improved seed verities. Therefore, peasants require GF to facilitate production. It enables access to high technology, and extensive use of fertilizers and pesticides means more environmental threats. Therefore, the agricultural procedures should be accomplished more pragmatically rather than wide usage of farming inputs.

The government and the private sector should be the chief players in the research and development process. Thus, both players must develop environmentally friendly and innovative technologies to facilitate the agricultural sector that ensures FS (Alimkulova and Aitmukhanbetova, 2020; Khanal and Omobitan, 2020).

Data availability statement

The original contributions presented in the study are included in the article/supplementary material; further inquiries can be directed to the corresponding author.

Author contributions

Conceptualization was completed by YH and ZS. The methodology was created by ZS. MA. The software and validation were handled by RY; MA. ZU completed the formal analysis while the research, resources, and data curation were handled by YH. The writing—original draught preparation was handled by YH, RY, ZS, MA, and ZU while writing—review and editing were completed by RY, MA, RY, ZU, and YH. The visualization was overseen by ZU, RY; and supervision was done by YH and ZU.

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Conflict of interest

YH was employed by Bank of Jiujiang, Jiangxi Province, China. While RY was employed by the Industrial and Commercial Bank of China.

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

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