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Fully Modified Least Squares Modeling Of Wheat Crop Production

Rajarathinam, A.[1] and Suba, S.S.[2]

Abstract

This paper investigates the dynamic relationships between area and production of the wheat crop during 1989-90 to 2020-2021 in different districts of Gujarat state, India. Pedroni cointegration test reveals the long-run equilibrium relationships between area and production of wheat, and the pairwise Granger causality test ensures cointegration relationships. Furthermore, the estimated long-run Panel Fully Modified Least Squares model was highly significant, which explains the 86 % of variations in wheat production. Furthermore, the long-term coefficient is positive and highly significant, indicating the existence of positive long-run equilibrium relationships between the study variables.

JEL classification numbers: E18, HO, I1, J64, J88.
Keywords: Cross-sectional dependence test, Panel cointegration test, Fully Modified Least Squares, Granger causality test, Levin-Lin-Chu unit root test.

[1] Manonmaniam Sundaranar University, Tamil Nadu, India.
[2] Manonmaniam Sundaranar University, Tamil Nadu, India.

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1. Introduction

Wheat (*Triticum aestivum*)occupies the prime position among the food crops in the world. In India, it is the second most important food crop next to rice and contributes to the country's total food grain production of about 25 %. Therefore, wheat has played a vital role in stabilizing the food grain production in the country over the past few years. In India, the wheat crop is grown mainly in the northern and western states. Uttar Pradesh is the topmost contributor of wheat, with a total production of 25.22 million tonnes, followed by Punjab (15.78 MT) and Madhya Pradesh (14.18 MT) (Rao and Naidu, 2021).

Wheat grows in winter in Gujarat. Forty-nine thousand hectares have been planted in Saurashtra. In addition, the wheat crop has been planted in Somnath at 16 thousand hectares and in Junagadh district at 16 thousand hectares. Wheat cultivation is zero in Kutch, North Gujarat, and South Gujarat. In 2020, wheat production in India, including Gujarat, may break a record for the second consecutive year. The Gujarat government had set a target of producing 43.64 lakh tonnes of wheat in 13.83 lakh hectares in 2019-20. Average production of 3155 kg per hectare was also expected. In 2018-19, the Gujarat government had an estimated production of 3019 kg per hectare, with 24 lakh tonnes in 7.97 lakh hectares (Anonymous, 2020).

Khapedia et al. (2018) employed univariate autoregressive integrated moving averages (ARIMA) to forecast the wheat area, production, and productivity of Madhya Pradesh using the historic data from 1981-82 to 2015-16. ARIMA (0,1,0) & (0,1,1) model was found suitable for all India and Madhya Pradesh area (million hectares), whereas ARIMA (O,1,1) & (0,1,0) was best fitted for forecasting wheat productivity (yield kg ha-1), in India and Madhya Pradesh. ARIMA (1,1,0) & (3,1,0) model was found in production (million tons) in India and Madhya Pradesh.

Nisha et al. (2019) examined the growth and instability in the area, production, and productivity of wheat crops in Haryana and India. They found the variability and instability among the three aspects, i.e., area, production, and productivity. However, the study result revealed positive trends in the production and yield of wheat for both Haryana and India.

Rao and Naidu (2021) employed various non-linear models to forecast the area, production, and productivity of wheat crops grown from 1949-50 to 2018-19 in India. Different non-linear models were employed to study the trends in the area, production, and productivity. The study revealed that all the models exhibited significance. The cubic model was found suitable to fit the trends in area and production, while the quadratic model for productivity with the highest adjusted coefficient of determination of wheat crop grown in India. The results indicated that the area, production, and productivity of wheat crops grown in India, had been shown to the increasing trend in the future.

The main objectives of the present investigations are to study the cointegration relationships, study the long-run equilibrium relationship, and causal relationships between the area and production of wheat crops grown in different districts of

Gujarat state, India, during 1995-2020 based on panel cointegration tests, FM-OLS model and Pair-wise Granger causality tests.

2. Materials and Methods

2.1 Materials

The time-series data on the area and production of wheat crops grown in different districts of Gujarat state from 1995-96 to 2019-2020 have been collected from the website, www.dag.gujarat.gov.in, maintained by the Department of Agriculture, Gujarat Government, Gujarat state. EViews Ver.11. was used for the model selection and diagnostics.

2.2 Methods

2.2.1 Unit root tests

Unit roots in panel data can be tested using either the Levin et al. (2002) test or the Hadri (2000) Lagrange multiplier (LM) stationarity test. The null hypothesis is that the panels contain unit roots, and the alternative hypothesis is that the panels are stationary. In the results, if the p-value is less than 0.05, then one can reject the null hypothesis and accept the alternative hypothesis.

2.2.2 Panel cointegration test

In the model, if the study variables area and prodn contain a panel unit root, one should test whether a long-run equilibrium relationship exists between the study variables. We use the Pedroni (2004) test to examine for panel cointegration, allowing both heterogeneities in the intercepts and slopes of the cointegrating equation. In his test, Pedroni (2004) provides seven statistics to test the null hypothesis, which means no cointegration in heterogeneous panels. One part of seven statistics is entitled “within dimension,” which considers common time factors and allows for heterogeneity across countries. The other part is termed “between dimension,” which provides parameter heterogeneity across countries. The established seven statistics by Pedroni (2004) that we employ are as follows:

Within dimension (panel tests):

i. Panel v-statistic
ii. Panel Phillips–Perron type r-statistics.
iii. Panel Phillips–Perron type t-statistic.
iv. Panel augmented Dickey-Fuller (ADF) type t-statistic.

Between dimensions (group tests):

i. Group Phillips–Perron type r-statistics.
ii. Group Phillips–Perron type t-statistic.
iii. Group ADF type t-statistic.

These seven statistics are based on the estimated residuals from Pedroni's (2004) estimated panel regression. In this panel regression, the null hypothesis tested whether it equals unity. In addition, Pedroni (2004) tabulated the finite sample distribution for the seven statistics using Monte Carlo simulations. If the test statistics exceed Pedroni's critical values, the null hypothesis of no cointegration is rejected, implying that a long-run relationship exists between the study variables (Karimi and Karamelikli, 2016).

2.2.3 Fully Modified Least Square Regression

The *Fully Modified Least Square Regression* (FM-OLS) regression was initially designed in work by Phillips and Hansen (1990**)** to provide optimal estimates of cointegrating regressions. The method modifies least squares to account for serial correlation effects and the endogeneity in the regressors resulting from a cointegrating relationship. The fully modified OLS principles can accommodate considerable heterogeneity across individual members of the panel. Also, it allows researchers to selectively pool the long-run information contained in the panel while permitting the short-run dynamics and fixed effects to be heterogeneous among different panel members. FMOLS models are categories of multiple time series models that directly estimate the long-run effect of the independent variables on the dependent variables after correcting for the endogeneity problem in the time series.

2.2.4 Testing for causality (Granger, 1969)

The causal relationship between two stationary series Xt (AREA) and Yt (PRODN) can be assessed based on the following bivariate autoregression:

$$X_t = \varphi_0 + \sum_{k=1}^{p} \varphi_k Y_{t-k} + \sum_{k=1}^{p} \phi_k X_{t-k} + \upsilon_t \qquad Y_t = \alpha_0 + \sum_{k=1}^{p} a_k Y_{t-k} + \sum_{k=1}^{p} \beta_k X_{t-k} + u_t$$

where p is a suitable chosen positive integer; α_k k=0,1,2,3,…,p, are constants; u_t and υ_t are the usual disturbance terms with zero mean and finite variance. The null hypothesis that X_t does not Granger-cause Y_t is rejected if β_k k>0 in the first equation is jointly significantly different from zero according to a standard joint test (e.g., an F test). Similarly, Y_t Granger causes X_t if the coefficients of ϕ_k and k>0 in the second equation are jointly different from zero. A bidirectional causality (or feedback) relation exists if both β_k and ϕ_k k>0 are different from 0.

3. Results and Discussion

3.1 Summary statistics

The summary statistics results presented in Table 1 and depicted in Figure 1 reveal that the area under the wheat crop was maximum (32909) in Ahmedabad district, followed by Junagadh (22544) and Sabarkantha (22212) districts. The lowest was in the Surat district (1686).

The areas under the wheat crop are normally distributed in all the districts except the Panchmahals and Surat districts, as the Jarque-Bera statistics values are non-significant.

The areas under the wheat crop are negatively skewed in Bharuch, Gandhinagar, Kheda, and Mehsana districts. For example, figure 2 depicts that more than 32000 hectares are under the wheat crop in Ahmedabad district; 14000 to 25000 hectares areas are the wheat crop in Junagadh, Sabarkantha, Kheda, Mehsana, Banaskantha, and Rajkot districts; 4000 to 9000 hectares areas are under the wheat crop in Surendranagar, Panchmahals, Gandhinagar, Jamnagar, Vadodara, Kutch, Amreli, Bharuch and Bhavnagar districts; nearly 1700 hectares area are under the wheat crop in Surat district.

The summary statistics results presented in Table 2 and depicted in Figure 3 reveal that the production of the wheat crop was maximum in Junagadh (86940) followed by Ahmedabad (66231) and Sabarkantha (66231) districts. The lowest was in the Surat district (3961).

The wheat crop productions in different districts of Gujarat state are normally distributed except in the Panchmahals, Surat, and Amreli districts, as the Jarque-Bera statistics (Jarque and Bera, (1987)) values are non-significant. However, the areas under the wheat crop are negatively skewed in Gandhinagar and Mehsana districts.

Figure 4 depicts that more than 80000 tons production of the wheat crop has been registered in Junagadh district; 40000 to 70000 tons of wheat production have been reported in Ahmedabad, Sabarkantha, Rajkot, Mehsana, Banaskantha, and Kheda districts; 10000 to 25000 tons of wheat productions in Surendranagar, Jamnagar, Gandhinagar, Amreli, Kutch, Vadodara, Panchmahals and Bhavnagar districts; 3000 to 8000 tons in Surat and Bharuch districts.

Table 1: Summary statistics of the area under the wheat crop

Sr.No.	District	Sum	Max.	Min.	Skew.	Kur.	p-value
1	Ahmedabad	32909	2304	487	0.406	2.578	0.908
2	Banaskantha	16984	932	390	0.124	1.684	0.379
3	Vadodara	5782	475	60	0.836	3.502	0.192
4	Bharuch	4788	293	57	-0.722	3.667	0.254
5	Gandhinagar	6107	438	65	-0.397	1.843	0.344
6	Kheda	18157	1004	366	-0.185	3.335	0.874
7	Mehsana	17240	902	313	-0.775	3.109	0.271
8	Panchmahals	6157	707	34	1.703	5.609	0.000
9	Sabarkantha	22212	1795	215	0.579	2.790	0.473
10	Surat	1686	135	37	1.536	6.095	0.000
11	Amreli	5034	550	26	0.900	3.124	0.171
12	Bhavnagar	4231	495	10	0.920	3.071	0.160
13	Jamnagar	5959	604	8	0.402	1.683	0.275
14	Junagadh	22544	2100	58	0.604	2.309	0.350
15	Kutch	5475	357	79	0.135	1.755	0.415
16	Rajkot	14570	1702	29	0.728	2.393	0.260
17	Surendranagar	8561	669	119	0.897	3.104	0.174

Table 2: Summary statistics of production of wheat crop

Sr.No.	District	Sum	Max.	Min.	Skew.	Kur.	p-value
1	Ahmedabad	66231	5476	785	0.469	2.129	0.412
2	Banaskantha	47160	2903	946	0.201	1.606	0.320
3	Vadodara	14489	1326	144	1.125	3.685	0.060
4	Bharuch	7268	473	118	0.178	1.787	0.421
5	Gandhinagar	19690	1417	172	-0.316	1.782	0.361
6	Kheda	45967	2712	868	0.208	1.847	0.443
7	Mehsana	49574	2801	834	-0.552	2.467	0.443
8	Panchmahals	12778	1561	63	1.587	4.414	0.002
9	Sabarkantha	60135	5267	380	0.430	2.608	0.617
10	Surat	3961	302	82	1.066	4.059	0.047
11	Amreli	16774	2082	59	1.206	4.018	0.024
12	Bhavnagar	11873	1600	23	1.180	3.895	0.032
13	Jamnagar	20231	2199	27	0.574	1.832	0.234
14	Junagadh	86940	9059	137	0.835	2.926	0.220
15	Kutch	15465	1040	203	0.155	1.721	0.391
16	Rajkot	54286	6783	66	0.857	2.696	0.194
17	Surendranagar	22454	2071	217	0.930	3.081	0.153

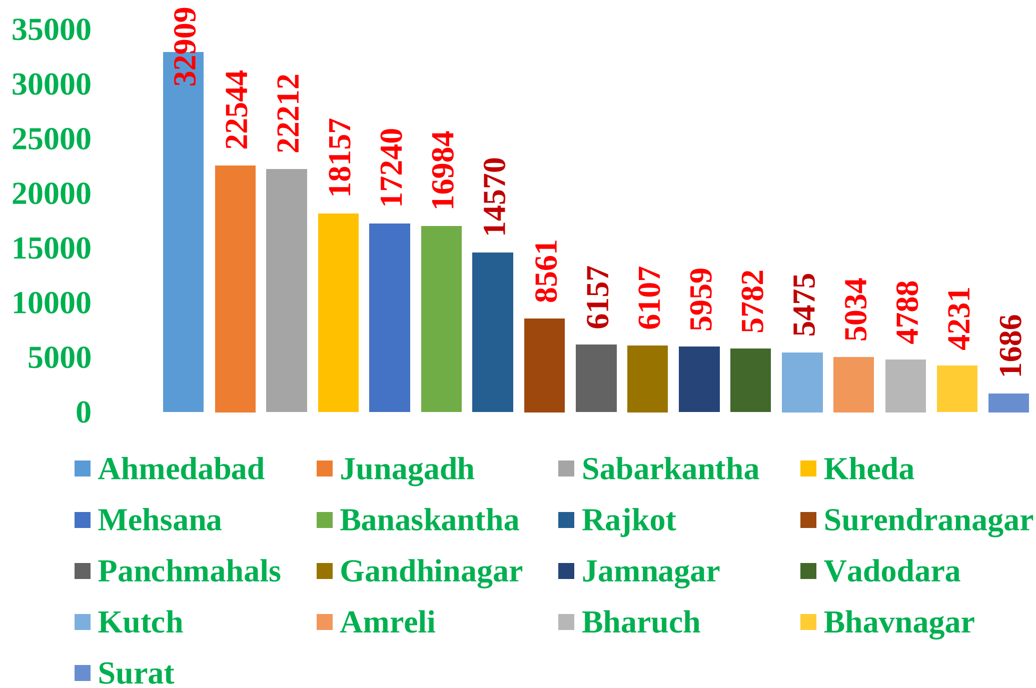

Figure 1: District-wise area under the wheat crop

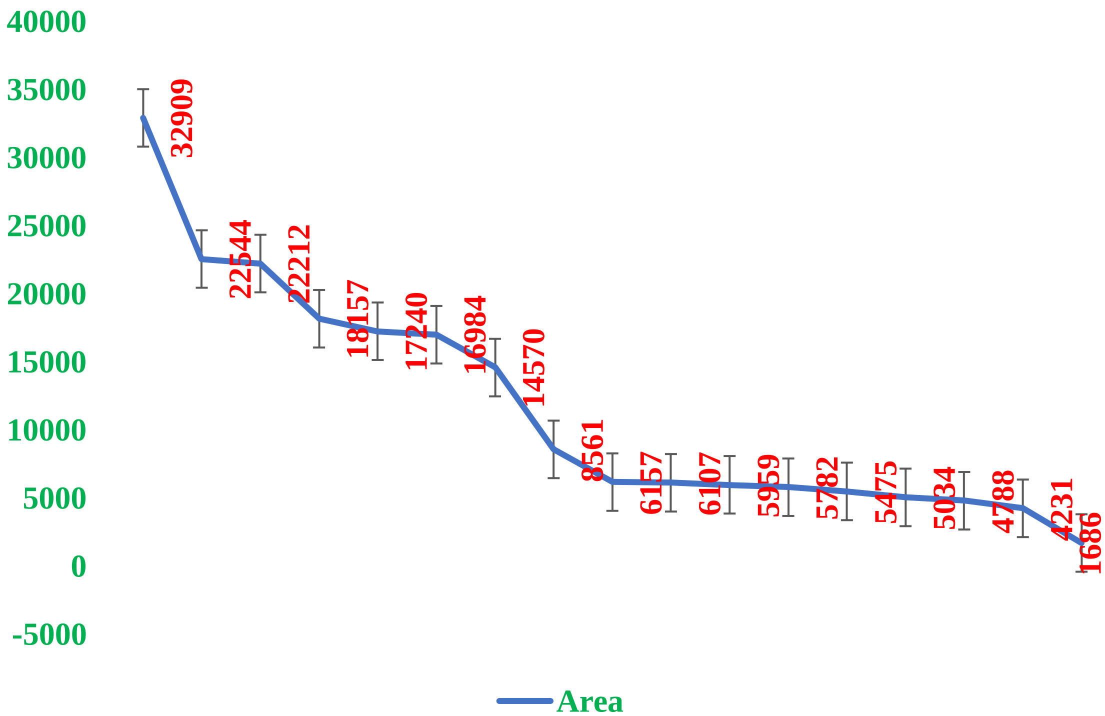

Figure 2: District-wise details of the area under the wheat crop

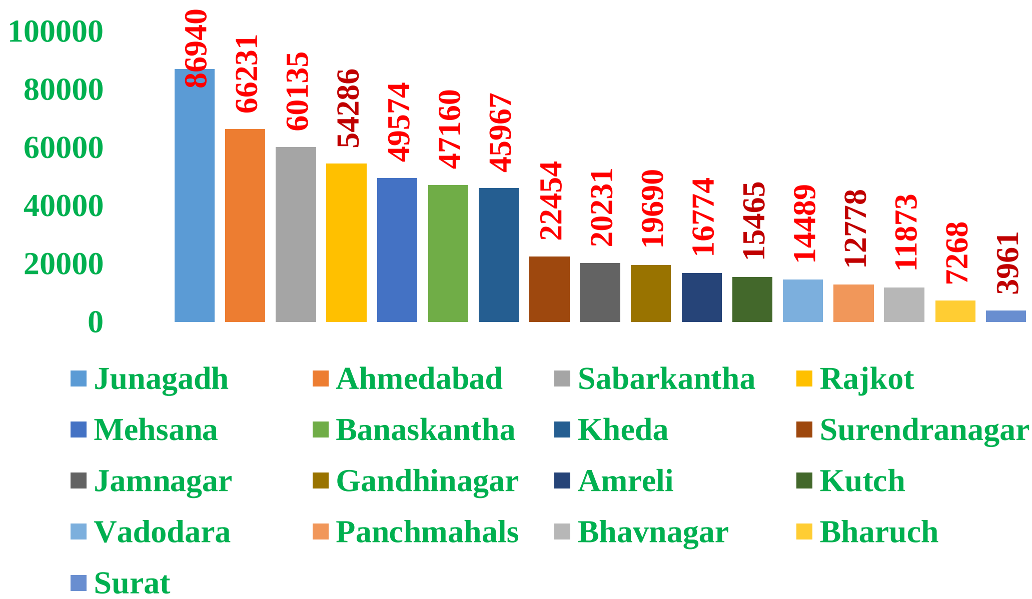

Figure 3: District-wise production of wheat crop

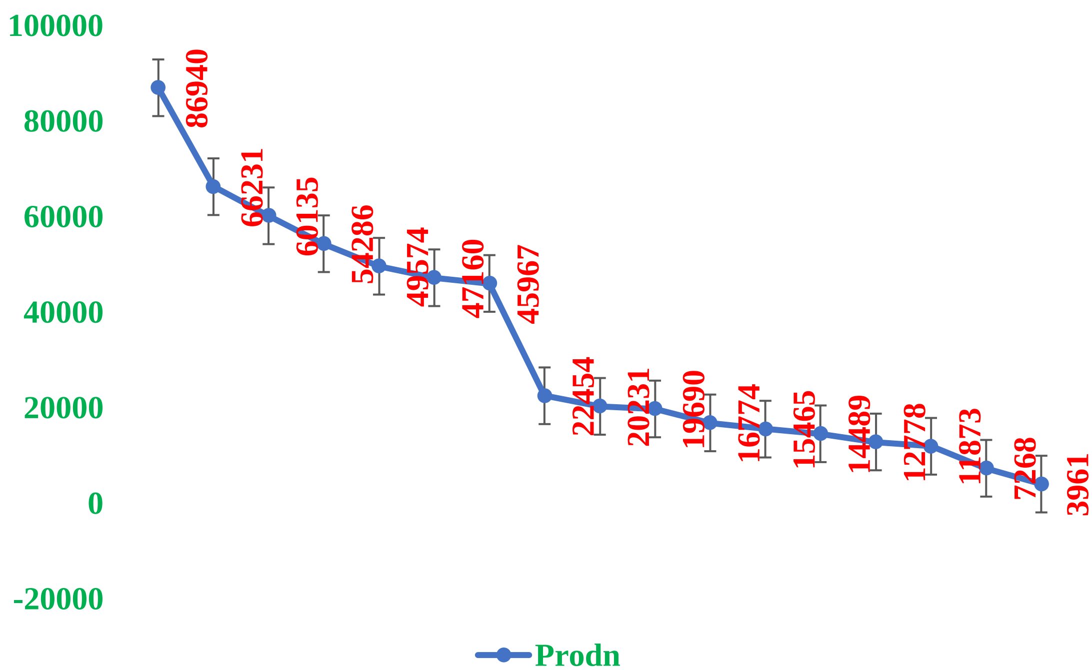

Figure 4: District-wise details of the production of wheat crop

The year-wise area under the wheat crop and its production are depicted in Figure 5.

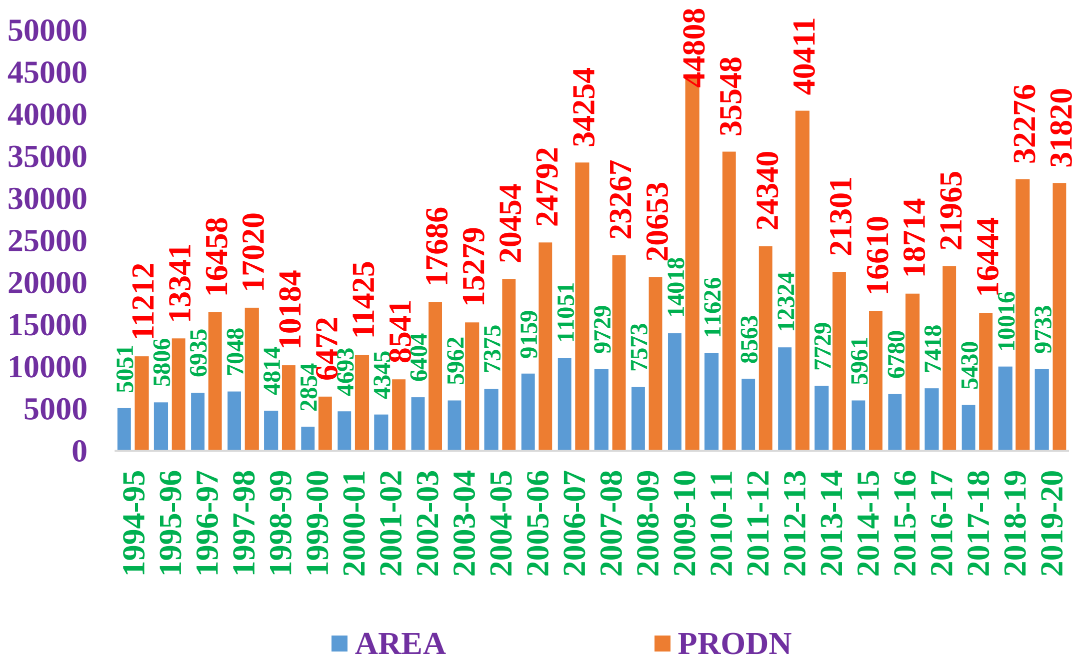

Figure 5: Year-wise area and production of wheat crop

3.2 Unit root tests

In analyses of time series data, the study variables must be stationary, which means that the means and variances of the variable data are the same. Accordingly, Levin-Lin-Chu unit root tests were carried out to test the stationarity of the study variables.

The test results are presented in Table 3. revealing the two variables under study, area, and prodn, to be stationary in level since the Levin, Lin, and Chu t-statistics are found to be highly significant ($p<0.0000$). Hence, the variables under study are found to be stationary.

Table 3: Characteristics of unit root test

Method	Variable	Statistic	Prob.**
Levin, Lin & Chu t*	AREA	-4.791	0.000
	PRODN	-2.592	0.005
** Probabilities are computed assuming asymptotic normality			

3.3 Pooled OLS regression Model or Constant Coefficients Model

The panel least squares method considers the production as the dependent variable and the area under the wheat crop as the independent variable. The regression results based on EViews, Version 11, are presented in Table 4.

The estimated model is

PRODN=-1138.29 + 2.91 *AREA **(R^2= 88%)**

Table 4: Characteristics of pooled OLS regression model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
AREA	2.912	0.051	57.132	0.000
C	-1138.286	68.091	-16.717	0.000
Root MSE	457.044	R-squared (%)		0.88
Mean dependent var	2547.348	Adjusted R-squared (%)		0.88
S.D. dependent var	1327.586	S.E. of regression		458.080
Akaike info criterion	15.096	Sum squared resid		92329034
Schwarz criterion	15.115	Log-likelihood		-3334.320
Hannan-Quinn criteria.	15.104	F-statistic		3264.060
Durbin-Watson stat	1.476	Prob(F-statistic)		0.000

The results reveal that the intercept and slopes are highly significant, and the model F-statistic is also highly significant, with a remarkably high R^2 of 88%. This model explains 88% of variations in wheat production. Additionally, for every unit increase in area under the wheat crop, the production is increased by 2.91%.

The major problem with this model is that it does not distinguish between the cross-sections, nor does it tell us whether the response of total production to the explanatory variable over time is the same for all cross-sections.

3.3.1 Investigating cross-sectional dependence

Cross-sectional dependence is essential diagnostics a researcher should investigate before performing panel data analysis. In this context, the Breusch and Pagan (1980) LM test, Pesaran (2004) scaled LM test, Pesaran (2004) CD test, and Baltagi et al. (2012) biased-corrected scaled LM test statistics values have been calculated and presented in Table 5.

Table 5: Characteristics of cross-sectional dependence test

Test	Statistic	d.f.	Prob.
Breusch-Pagan LM	3536.000	136	0.000
Pesaran scaled LM	206.155		0.000
Pesaran CD	59.464		0.000

The above table suggests rejection of the null hypothesis of no cross-sectional dependence, i.e., cross-section dependence among the regressors at a 1% significance level for the Breusch-Pagan LM and Pesaran scaled LM test. This means there is a certain level of dependence among districts of Gujarat state, thereby confirming the appropriateness of the panel data modeling to study the long-run relationships between area and production of wheat crops grown in different districts (cross-section) of Gujarat State.

3.4 Panel cointegration test

To estimate the cointegration relationship between the area and production of the wheat crop, the Pedronic cointegration test (Pedroni, 2000, 2004); (with no deterministic trend, deterministic intercept, and trend; and no deterministic intercept or trend) has been carried out. The test results are presented in Tables 6 through 8.

The Pedroni tests presented in Tables 6 through 8 reveal that out of eleven tests for the null hypothesis of no cointegration is rejected since most of the test statistics' p values are <0.0.000, indicating that there exists a cointegration, i.e., long-term relationship between the area and production of wheat crop

Table 6: Characteristics of Pedroni cointegration test (no deterministic trend)

Test Statistic	Statistic	Prob.	Weighted statistics	Prob.
Panel v-Statistic	3.671	0.000	3.671	0.000
Panel rho-Statistic	-9.049	0.000	-9.049	0.000
Panel PP-Statistic	-7.935	0.000	-7.935	0.000
Panel ADF-Statistic	-8.108	0.000	-8.108	0.000
Group rho-Statistic	-6.353	0.000		
Group PP-Statistic	-7.896	0.000		
Group ADF-Statistic	-8.102	0.000		

Table 7: Characteristics of Pedroni cointegration test (deterministic intercept and trend)

Test Statistic	Statistic	Prob.	Weighted Statistic	Prob.
Panel v-Statistic	3.372	0.000	3.372	0.000
Panel rho-Statistic	-5.291	0.000	-5.291	0.000
Panel PP-Statistic	-7.444	0.000	-7.444	0.000
Panel ADF-Statistic	-7.444	0.000	-7.444	0.000
Group rho-Statistic	-2.864	0.002		
Group PP-Statistic	-6.759	0.000		
Group ADF-Statistic	-6.759	0.000		

Table 8: Characteristics of Pedroni cointegration test (no deterministic intercept or trend)

Test Statistic	Statistic	Prob.	Weighted Statistic	Prob.
Panel v-Statistic	4.225	0.000	4.225	0.000
Panel rho-Statistic	-2.301	0.010	-2.301	0.010
Panel PP-Statistic	-2.254	0.012	-2.253	0.012
Panel ADF-Statistic	-2.342	0.009	-2.342	0.009
Group rho-Statistic	1.023	0.847		
Group PP-Statistic	-1.351	0.088		
Group ADF-Statistic	-1.473	0.070		

In the long run, all the two study variables can move together. So the variables under study have a long-run association ship. When the variables are cointegrated, there is validity to run the long-run model, such as the Panel FMOLS model (long-run model).

3.5 Panel Fully Modified Least Squares

To study the long-run equilibrium relationship between the area and the wheat crop production, the FMOLS method employed the area under the wheat crop as the independent variable and wheat production as the dependent variable. The results are presented in Table 9.

Table 9: Characteristics of panel fully modified least squares test

Name of Variable	Coefficient	Std.Error	t-Statistic	Prob.
AREA	3.187	0.064	49.765	0.000
R-squared %	0.86	Mean dependent var		2614.762
Adjusted R-squared %	0.86	S.D. dependent var		1309.469
S.E. of regression	491.641	Sum squared resid		98376190

The estimated long-run model is:

$$PRODNH = 3.187 * AREA + EQN\_01\_EFCT \qquad (R^2=86\ \%)$$

In Table 9, the long-term coefficient (3.187) is positive and highly significant (p<0.000), indicating the existence of positive long-run equilibrium relationships between the study variables. Finally, Table 10 and Figure 5., depict the coefficient of Confidence Intervals (CI), revealing that the estimated long-run coefficient (3.187) lies in the 99% CI.

Table 10: Characteristics of the coefficient confidence interval

Variable	Coefficient	90% CI		95% CI		99% CI	
		Low	High	Low	High	Low	High
AREA	3.187	3.081	3.292	3.061	3.313	3.021	3.353

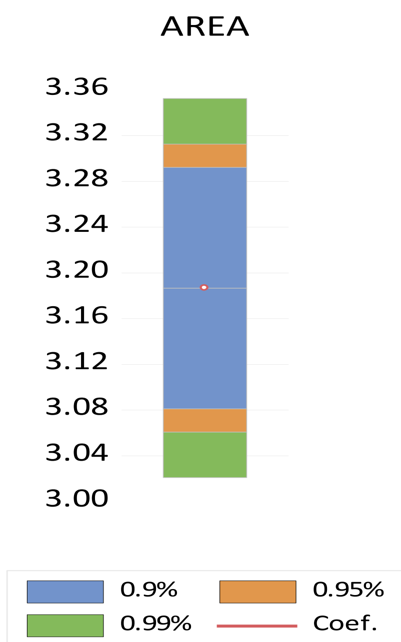

Figure 5: Estimated coefficient's confidence intervals

3.6 Test of causality

The Granger test of causality was employed to assess whether causal relationships exist among the variables and determine the direction of the causality. The results are presented in Table 11. The test results reveal that the null hypothesis of no causality between the independent and dependent variables running in either direction is rejected; hence, bidirectional causality exists between the study variables.

Table 11: Characteristics of Pairwise Granger Causality Test

Null - Hypothesis	Obs	F- Statistic	Prob.
AREA does not Granger Cause PRODN	408	204.478	5.E-62
PRODN does not Granger Cause AREA		202.583	1.E-61

4. Conclusion

The area under the wheat crop was maximum in Ahmedabad, followed by Junagadh and Sabarkantha districts. More than 32000 hectares are under the wheat crop in Ahmedabad district; 14000 to 25000 hectares areas are the wheat crop in Junagadh, Sabarkantha, Kheda, Mehsana, Banaskantha, and Rajkot districts; 4000 to 9000 hectares areas are under the wheat crop in Surendranagar, Panchmahals, Gandhinagar, Jamnagar, Vadodara, Kutch, Amreli, Bharuch and Bhavnagar districts; nearly 1700 hectares area is under the wheat crop in Surat district.

The wheat production was maximum in Junagadh, followed by Ahmedabad and Sabarkantha districts. More than 80000 metric tons of wheat production was registered in Junagadh district; 40000 to 70000 metric tons of wheat production have been reported in Ahmedabad, Sabarkantha, Rajkot, Mehsana, Banaskantha, Kheda districts; 10000 to 25000 metric tons of wheat production in Surendranagar, Jamnagar, Gandhinagar, Amreli, Kutch, Vadodara, Panchmahals and Bhavnagar districts; 3000 to 8000 metric tons in Surat and Bharuch districts.

Pedroni cointegration test reveals the long-run equilibrium relationships between area and production of wheat, and the pairwise Granger causality test ensures cointegration relationships. The estimated long-run Panel Fully Modified Least Squares model was highly significant, which explains the 86 % of variations in wheat production. In addition, the long-term coefficient is positive and highly significant, indicating the existence of positive long-run equilibrium relationships between the study variables.

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