Determinants of Food Grain Production in Indian States: Panel Cointegration and VECM Analysis

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Abstract

In this paper the author finds the link among the food grain production , gross state domestic product at current prices, net irrigated area, fertilizer used by states, cropping intensity, state fiscal deficit and state gross capital formation of 27 states in India from 1990-91 to 2015-16 using panel regression analysis, panel co-integration and vector error correction model. It finds positive link among food grain production, gross state domestic product at current prices, net irrigated area, NPK used by states, cropping intensity and negative relation with state fiscal deficit. Johansen-Fisher cointegration test confirmed four co-integrating equations. VECM is stable, not normally distributed and non-stationary with problem of autocorrelation. VECM states that there is significant long run association but in co-integrating equations change of food grain production and change of SDP have long run causality and they are moving towards equilibrium with slow speed of adjustment but change of net irrigated area and change of cropping intensity do not move to equilibrium level because they have no long run causality with the independent variables. On the other hand, there is short run causality running from state fiscal deficit to SDP and cropping intensity only but rest of the variables did not show any short run causality.

Keywords : *Food Grain Production, Panel Co-integration, Panel Vector Error Correction, Causality, Wald Test.*

JEL Codes: C12, C23, Q10, Q15, Q18

Introduction

Recent globalization produced a decline in costs of cross border trade in farm and other products as a result of reductions in governmental distortions to agricultural production, consumption and trade which have boosted economic growth and reduced global poverty especially in Asia. There has been a structural change in global agricultural market. There are remarkable paradigm shifts in the policy changes for climate and environment, high demand for bio-fuels, stimulation of international capital flows, effects of exchange rate of currencies and changes in WTO negotiations and clauses which had great influence in agriculture (Anderson, 2010).On the other hand, Food Security Information Network(2019) stated in the 2019 Global Report on Food Crises that more than 113 million people across 53 countries have been experiencing acute hunger of which 58% are in African countries,13% in South and South East Asian countries,24% in Middle East countries and 5% in Latin American countries. The U N Security Council called for humanitarian assistance of US$27.3 billion in 2017 to feed those hungry people. They noted that conflict and insecurity, eliminate climate shocks and economic turbulence are the main drivers of food insecurity. India contains one fourth of global hunger burden among nearly 195 million undernourished people in which 47 million or 4 out of 10 children in India are not meeting their full human potential because of chronic malnutrition or shunting. So the goal of Zero Hunger Challenge in India is fundamentally relevant. Because a few states in India such as Odisha, Bihar,Uttar Pradesh, West Bengal, Jharkhand, Chhattisgarh, Madhya Pradesh and Maharastra have been confronting with exstreme levels of food insecurity.

World food grain production in 2008-09 was 2.241 billion metric ton which rose to 2.62 billion metric ton in 2016-17 in which world wheat production was 585.4 million metric ton in 1996 that catapulted to 729 million metric ton in 2014 and world rice production will increase to 904 million ton in 2030 from 600 million ton in 2000 and 753 million ton in 2017.The global food production should be increased by 70% to feed the world in 2050 but farming are likely to be decreasing with 8% for 8 major food crops across Africa and South Asia.

India ranks second in world rice and wheat production contributing more than 21% and 11% of world rice and wheat output. Food grain constitutes 64% of the gross cropped area although it accounts less than 25% of the total value of output of agriculture and related activities. Food grains occupied an area of 97.32 million hectares in 1950-51 which has increased to 122.65 million hectares in 2016-17 and food grain production was 50.82 million ton in 1950-51 which stipulated to 277.49 million ton in 2017-18.In 1950-51, rice was 30.81 million ton which increased to 109.70 million ton in 2016-17 and wheat production was 9.75 million ton which catapulted to 97.11 million ton in 2016-17.

There are some basic factors such as area of production, net irrigated area, fertilizer and pesticides uses, labor and capital employed, cropping intensity, GDP and capital formation in agriculture which influence the food grain production directly. There are some external factors such as environment, government policy, and infrastructure which have impact on food grain production as well. Even, the biological factors like diseases, animal, human, insects, weeds can damage crops. Modern transportation, marketing, advertising and technology affect to grow more food production by increasing intensity of food production. Prohibiting food import and tax on import may increase intensity of food production. More credit outstanding may reduce intensity of food production. Recent studies emphasized that crop growth depends on internal factors or genetic factors such as[i]high yielding ability,[ii]early maturity,[iii] resistance to lodging,[iv] drought flood and salinity tolerance,[v]tolerance to insects, pests and diseases, [vi]chemical composition of grain,[vii]quality of grain and [viii]quality of straw. And the external factors or environmental factor that affects growth of crops are [i]climatic,[ii]edaphic, [iii]biotic,[iv] physiographic,[v]socio-economic. Climatic condition have six areas such [i]precipitation,[ii]temperature,[iii] atmospheric humidity[iv] solar radiation,[v] wind velocity and [vi] atmospheric gases. Besides, there are some important macro-economic factors which have great impact on the crop production in agriculture in India. To reduce the level of poverty the policy of enhancement of food grain production is urgent because an empirical test verified that a 1% increase in agricultural yields leads to a 0.6-1.2% reduction in the number of people living below $1 per day.

In this paper the author will study the association among food grain production , state domestic product, net irrigated area, NPK consumption, cropping intensity, fiscal deficit of the state and capital formation of 27 states of India from 1990-91 to 2015-16 with the help of panel regression, panel co-integration and panel vector error correction models.

Literature review

The author described a few important relevant literatures which are related to this issue. Stockdale (1948) examined that agricultural production in British colonies in Africa usually depended on soils, water, systems of agriculture, use of livestock, crop varieties, paste and diseases, marketing arragements and social organizations respectively. Al-Tahan (1982) explored that in Iraqi agriculture during 1950-1975 input factors were farm machinery, water resources, irrigation methods. There was no significant improvement on inputs during the period but there was impact of climate and weather factors. The intensity of irrigation was positive with agricultural production of food. Weather factors such as rain-fed area and rainfall distribution were positive with food production but air temperature and soil temperature were negative with food production. During the study period, wheat and burley production have increased with area of production but fluctuation varied since coefficient of variation were 64.3% and 50.7% and coefficients of variation of area under production were 30.4% and 17.8% for wheat and burley. Kwinarajit and William (2004) studied production of rice in Thailand during 1971-1999 and they took inputs as area planted, average rainfall, paddy prices and agriculture labor force using OLS with 9 types of models (lag 1) and current price deflated by PPI,GDP deflator, nominal and current price of rice, nominal and average price deflated by PPI and GDP. They found that area planted to rice was positively and significantly related to nominal price but not real prices. Area planted to rice was more responsive to past changes in area planted, the amount of rainfall, and availability of agricultural labor than to change in paddy rice prices. Variability of rainfall was also an important constraint to growth of rice production suggesting the importance of government investment in irrigation system to reduce the risk of water shortage. Only exception was that the estimated price coefficients in four models were negative. Muhammad, Munir and Siddiqui (2007) showed that in India during 1949-50-1997-98 ,there had been increasing trends of percentage coverage under irrigation, production of rice in hectares and the percent of yield. Rahman and Parvin (2009) explored that the impact of irrigated area showed positive result on production of rice especially Aus, Aman and Boro and also rose cropping intensity which greatly contributed to agricultural GDP in Bangladesh during 1980-81 to 2006-07. The study of Chittedi and Bayya (2012) explained that there was a significant positive relation between public expenditure and irrigation development in Andhra Pradesh (India) during 1990-2008 which increased gross area cultivated. Thus, overall impact of it was positive toward agricultural production and also led to grow more of multiple cropping. Brownson, Vincent, Emmanuel and Etim (2012) studied that export, external reserves, inflation rate and external debt have significant negative short run and long run relationship with agricultural productivity in Nigeria during 1970-2010 which were found through unit root test, cointegration test and vector error correction model. Chand and Parappurathu (2012) found multiple structural breaks in GDP in agriculture. The trend in agricultural growth from 1960-61 to 2010-11 showed upward cyclically and the states activities were categorized into greater than 4% growth rate, 2% growth rate and less than 2% growth rate. The eastern India performed the worst showing less than 2%.The authors found major drivers of agricultural growth in India which are capital formation, primary inputs, terms of trade of agriculture vis-à-vis non-agriculture, technology, cropping intensity, institutional credit and electricity.

Xaba and Masuku (2013) examined that the vegetable production was positively related with price of vegetable, family labor, distance to market, area under cultivation, fertilizer used, quantity produced in Swaziland. They used OLS method taking 100 farmers as sample .They took dummy variables such as sex of farmers, education of farmers, access to extensive service, access to credit by farmers and marketing agreements which were found positive with vegetable production .Wongnaa (2013) studied cashew production at Wenchi municipality in Ghana taking 140 respondent as sample for OLS. He found that cashew production was positively related with farm size, fertilizer used, pesticides, pruming, education and contact with extension officers while labor ,years of experience(labor in man days) are inversely related. But, physical capital was also positively related with cashew production. Mapfumo (2013) examined empirically during 1980-2010 in Zimbabwe on the linkage between agricultural production and economic growth and found that the value of agricultural production of tobacco, maize and cotton positively affected economic growth in Zimbabwe.

Di-Marcantonio, Merceles-Opazo, Barreirro-Hurle and Demeke (2014) studied 41 African countries taking cross country panel samples during 1968-2008.They used fixed effect model of panel regression among agricultural output of food as target variable and independent variables were land, irrigation, fertilizer, animals for transport, tractors, labor as inputs ,urbanization, land locked telephone line as market access, export, cereal aid, policy score, inflation as macroeconomic environment, school enrollment as human capital access and rain dummy and battle dummy as environment factors. All factors are significantly positively related but land locked dummy food aid is significantly negative relation with agricultural food production where rain dummy is insignificantly positive and conflict dummy is insignificantly negative. Sasmal (2014) verified through econometric model that there was a long run relationship between yield of food grain production and net irrigated area which was significantly positive in India during 1970-71-2007-08 and it was also true for NPK used. Kulshrestha (2014) examined econometric analysis of agricultural productivity in Rajasthan during 1990-2010 covering all districts for 16 crops to apply panel data in the models of cointegration and vector error correction. The study found that the cropping intensity and crop irrigated area had significant impact in enhancing productivity of a few crops and fertilizer consumption played a key role in all crops for increasing productivity except soya bean, cotton, kharif pulses etc. The contribution of road length had significant role in productivity of wheat, pearl, millet, barley, ground nut, maize, rice and kharif pulse.

Deshpande (2017) found out several factors of agricultural productivity in India which were availability and quality of agricultural inputs such as land, water, seed, fertilizer, access to agricultural credit, crop insurance, agricultural support price, storage, marketing, infrastructure and post-harvest activities and so on. Rehman and Luan (2017) studied an econometric analysis in China during 1980-2015 on the relationship between agricultural crop and agricultural GDP applying OLS and cointegration test and found a significant positive link between them. Priyadarshini and Nayak (2018) examined short run and long run effects of factors on agricultural productivity in India during 1980-2013 through cointegration and vector error correction model. The results suggested that there was long run equilibrium relationship between the determinants and the productivity. VECM showed that there were long run causalities running from irrigation, fertilizer, non-product specific support to inputs, electricity and private investment in agriculture. Even there were short run causalities running from irrigation and private investment to agricultural productivity. Pradhan and Mukherjee (2018) estimated the technical efficiency of agricultural production in India during 1999-2007 applying production frontier model for both cross section and panel data and found that farmer's education, household production process, proportion of irrigated area, availability of wells, yielding variety of lands, government services, agricultural expenditure by local government and women reservation in local government significantly contributed to the efficiency of production.

Methodology and Data

The paper assumed that

$y = production\ of\ food\ grain\ (in\ thousand\ ton)$

$x_1 =\ State\ Domestic\ Product\ at\ current\ prices\ (in\ Rs\ lakh)$

$x_2 = net\ irrigated\ area\ (in\ thousand\ hectares)$

$x_3 = NPK\ used\ (in\ kg / hectares)$

$x_4 = cropping\ intensity\ \%:$

$x_5 =\ state\ Fiscal\ Deficit\ (in\ billion\ Rs)$

$x_6 = state\ gross\ capital\ formation, (in\, million\ Rs)$

Author has included the following states in India: 1. Andhra Pradesh, 2. Arunachal Pradesh, 3. Assam, 4. Bihar, 5. Delhi, 6. Goa, 7. Gujarat, 8. Haryana, 9. Himachal Pradesh, 10. Jammu & Kashmir, 11.Karnataka, 12. Kerala, 13. Madhya Pradesh, 14.Maharastra, 15.Manipur, 16. Meghalaya, 17.Mizoram, 18.Nagaland, 19.Odisha, 20.Pondichery, 21.Punjab, 22.Rajasthan, 23.Sikkim, 24.Tamilnadu, 25.Tripura, 26.Uttar Pradesh and 27.West Bengal.

All the secondary data on the above variables have been collected from Reserve Bank of India from 199-91 to 2015-16.

To examine the relationship among the food grain production with those independent variables of 27 states in India during the specified period, the author used fixed effect panel regression model after verifying the Hausman Test (1978). Residual cross section dependence test of Breausch-Pagan LM (1979), Pesaran scaled LM (2004), A Bias –corrected scaled LM test of Pesaran, Ullah & Yamagata (2008) and Pesaran CD (2004) test have been applied. Fisher (1932) -Johansen co-integration test (1991) was used to verify co-integration. Johansen (1991) Panel VECM was also used to show long and short run association where the Wald test (1943) verified the short run causality in the system equations.

Findings of the Models

To find the link among the food grain production , gross state domestic product at current prices, net irrigated area, NPK used by states, cropping intensity, state fiscal deficit and state gross capital formation of 27 states in India from 1990-91 to 2015-16,the author has used panel regression analysis. Using random effect model with period 24, cross section 22 and total observation 516, the panel regression was shown the following Table 1.

Table 1: Random Effect Model

variables	*coefficients*	*SE*	*T statistic*	*probability*
C	2.072501	0.593382	3.492693	0.0005
$Log(x_1)$	0.122551	0.015845	7.734470	0.0000
$Log(x_2)$	0.327009	0.027606	11.84551	0.0000
$Log(x_3)$	0.056487	0.022579	2.501696	0.0127
$Log(x_4)$	0.402222	0.119529	3.365052	0.0008
$Log(x_5)$	−0.008926	0.005168	−1.727367	0.0847
$Log(x_6)$	0.006468	0.005690	1.136655	0.2562

R^2=0.39,F=54.46 ,DW=1.01,*=significant at 5% level.*

The Hausman test for random effect model is tested where the value Chi-Square statistic with 6 degree of freedom is 154.426398 which rejected the Null hypothesis because probability is less than 5% .Thus the alternative hypothesis- the fixed effect model is considered as appropriate.

Now, the panel fixed effect regression model is estimated which is shown below in Table 2 where total observation =516, cross section=22 and period=24.

Table 2: Fixed Effect Model

variables	*coefficients*	*SE*	*t statistic*	*probability*
C	−6.305664	0.622548	−10.12880	0.0000
$log(x_1)$	0.177195	0.030197	5.868040	0.0000
$log(x_2)$	0.706699	0.021477	32.90521	0.0000
$log(x_3)$	0.057806	0.025805	2.240075	0.0255
$log(x_4)$	1.503085	0.127443	11.79416	0.0000
$log(x_5)$	−0.059990	0.011048	−5.430027	0.0000
$log(x_6)$	−0.015924	0.010085	−1.578964	0.1150

R^2=0.928, F=1102.63, DW=0.37,*=significant at 5% level.*

This fixed effect panel regression equation states that one per cent increase in SDP at current prices, net irrigated area, NPK used, cropping intensity, state fiscal deficit and state gross capital formation per year led to 0.177 %, 0.7066%, 0.0578%, and 1.5099%, increase in food grain production per year respectively and decrease of 0.0599% and 0.0159% food grain production per year from 1990-91 to 2015-16 in 27 Indian states. All coefficients are significant at 5% level except state gross capital formation. The regression equation is a good fit with high R^2, significant F and insignificant DW which indicates serial correlation problem.

Residual cross section dependence test assured that there is no cross section dependency since the test statistic of

Breausch-Pagan LM, Pesaran scaled LM, Bias –corrected scaled LM and Pesaran CD have been rejected from Null Hypothesis of no cross section dependence (correlation) in residuals which are given below in Table 3:

Table 3: Residual cross section dependence test

Test	*Statistic*	*df*	*Probability*
Breusch – Pagan LM	631.0239	231	0.0000
Pesaran scaled LM	17.58726		0.0000
Bias – corrected scaled LM	17.10900		0.0000
Pesaran CD	3.372049		0.0007

Now, the author is interested to study the co-integrating relationship or long run association among food grain production ,state gross domestic product at current prices, net irrigated area of states, utilization of NPK of states, cropping intensity of states, fiscal deficit of states in India from 1990-91 to 2015-16 using panel co-integration model. All the series have been converted to first difference series showing stationary series after elimination of unit root. Johansen- Fisher panel Co-integration Test is applied using log which includes 702 observations with 22 cross sections and linear deterministic trend in unrestricted co-integration rank test. Trace Test showed four co-integrating equations and Max Eigen test showed three co-integrating equations which are significant. These are given in the Table 4.

Table 4: Panel Cointegration test

Hypothesized No. of CE(s)	*Fisher Stat.* (from Trace test)*	*Probability.*	*Fisher Stat.* (from Max – Eigen test)*	*Probability.*
None	852.3	0.0000	516.6	0.0000
At most 1	399.3	0.0000	277.4	0.0000
At most 2	177.9	0.0000	128.1	0.0000
At most 3	84.59	0.0009	61.91	0.0855
At most 4	55.91	0.2022	49.72	0.4047
At most 5	61.22	0.0953	61.22	0.0953

** Probabilities are computed using asymptotic Chi-square distribution*

In Table 5, Individual cross section results have been arranged showing further verification of cointegration.

Table 5: Cross section of co-integration

Hypothesized No. of CE(s)	*Fisher Stat.* (from Trace test)*	*Probability.*	*Fisher Stat.* (from Max – Eigen test)*	*Probability.*
Hypothesis of at most 4 *co – integration relationship*				
1	13.8815	0.0863	11.4335	0.1338
2	6.8776	0.5919	5.2566	0.7092
3	11.1662	0.2015	11.0035	0.1540
4	6.8736	0.5924	6.8434	0.5078

Since, there is co-integration among variables, then the estimates of VECM have been calculated and these are given below in the matrix form.

$$\begin{bmatrix} \Delta \log y \\ \Delta \log x_{1t} \\ \Delta \log x_{2t} \\ \Delta \log x_{3t} \\ \Delta \log x_{4t} \\ \Delta \log x_{5t} \end{bmatrix} = \begin{bmatrix} 0.0108 \\ 0.1469 \\ 0.0247 \\ 0.0445 \\ 0.0015 \\ 0.0960 \end{bmatrix} + \begin{bmatrix} -0.02356 \\ -0.0253 \\ 0.05268 \\ 0.00465 \\ 0.00944 \\ -0.7166 \end{bmatrix} [EC]$$

$$+\begin{bmatrix} -0.5152 & -0.20936 & 0.04503 & 0.0265 & 0.02652 & 0.01115 & 0.01559 & 0.00267 & -0.2647 & 0.0772 & 0.01119 & 0.00832 \\ -0.0258 & -0.00118 & -0.3708 & -0.054 & -0.0267 & 0.0176 & -0.0046 & 0.01521 & 0.1342 & -0.0238 & 0.00835 & 0.02067 \\ -0.0387 & -0.0408 & 0.0148 & -0.0535 & 0.5325 & -0.24239 & -0.0193 & -0.0558 & 0.2321 & 0.0238 & -0.0196 & -0.0168 \\ -0.0733 & -0.0275 & -0.0578 & -0.1134 & -0.01108 & -0.0409 & -0.1206 & -0.1408 & 0.39201 & 0.02805 & 3.49E-05 & -0.00575 \\ -0.0116 & 0.0028 & 0.0154 & -0.0197 & 0.00205 & -0.00154 & 0.00408 & 0.0032 & -0.1165 & -0.0556 & -0.00663 & -0.00523 \\ 0.6889 & 0.5547 & 0.8338 & -0.9188 & 0.01267 & -0.21135 & -0.2169 & -0.02501 & -1.962 & -0.0802 & -0.0409 & -0.0490 \end{bmatrix}$$

$$\mathbf{x} \begin{bmatrix} \Delta \log y_{t-1} \\ \Delta \log y_{t-2} \\ \Delta \log x_{1t-1} \\ \Delta \log x_{1t-2} \\ \Delta \log x_{2t-1} \\ \Delta \log x_{2t-2} \\ \Delta \log x_{3t-1} \\ \Delta \log x_{3t-2} \\ \Delta \log x_{4t-1} \\ \Delta \log x_{4t-2} \\ \Delta \log x_{5t-1} \\ \Delta \log x_{5t-2} \end{bmatrix}$$

The estimated VECM-1 is not a good fit (where R^2=0.227,F=11.07, AIC=-0.338459,SIC=-0.220809) yet the coefficient of error correction is significant and negative which represents that it moves towards equilibrium. .

Δ log(y) is significantly related with Δlog(y_{t-1}) and Δlog(y_{t-2}) negatively

Here the estimated VECM-2 is a bad fit because no coefficients are significant except error correction which implies that it is tending towards equilibrium (where R^2=0.16,F=7.157247, AIC=-0.621406,SIC=-0.503756).

The estimated VECM-3 is also a bad fit but Δlog(x_{2t}) is negatively significant with Δlog(x_{2t-1}) and Δlog(x_{2t-2}) and the coefficient of error correction term signifies divergent movement where R^2= 0.235217,F=11.54537*, AIC= 0.682662,SC=0.800312 .

The VECM-4 is a bad fit with divergent error correction although there is negative relation with Δlog(x_{3t}), Δlog(x_{3t-1}) and Δlog(x_{3t-2}) significantly where R^2= 0.035322,F=1.374502, AIC= 0.526776,SC=0.644426.

The VECM-5 is a bad fit with divergent error correction although there is negative relation with Δlog(x_{4t}), Δlog(x_{5t-1}) and Δlog(x_{5t-2}) significantly where R^2= 0.062818,F=2.516148, AIC= -3.013300,SC=-2.895650.

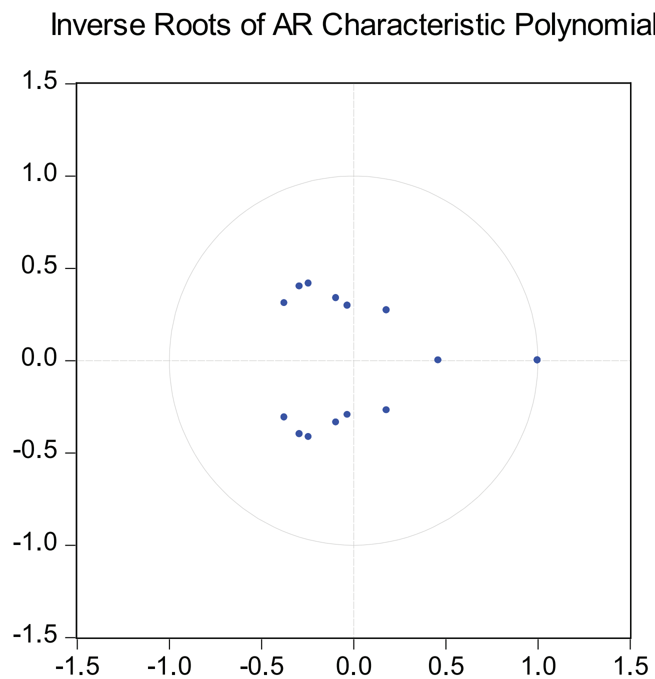
The estimated VECM-6 is also a bad fit but Δlog(x_{5t}) is significantly related with Δlog(x_{1t-2}) negatively and the error correction is negative and significant which implies that it moves towards equilibrium when R^2= 0.277780,F=14.43803, AIC= 3.811709,SC=3.929359.

This estimated VECM consists of 5 unit roots, 12 imaginary roots and one root is positive but less than one so that all roots lie on or inside the unit circle which proves that the model is stable but non-stationary.

Table 6: Values of Roots

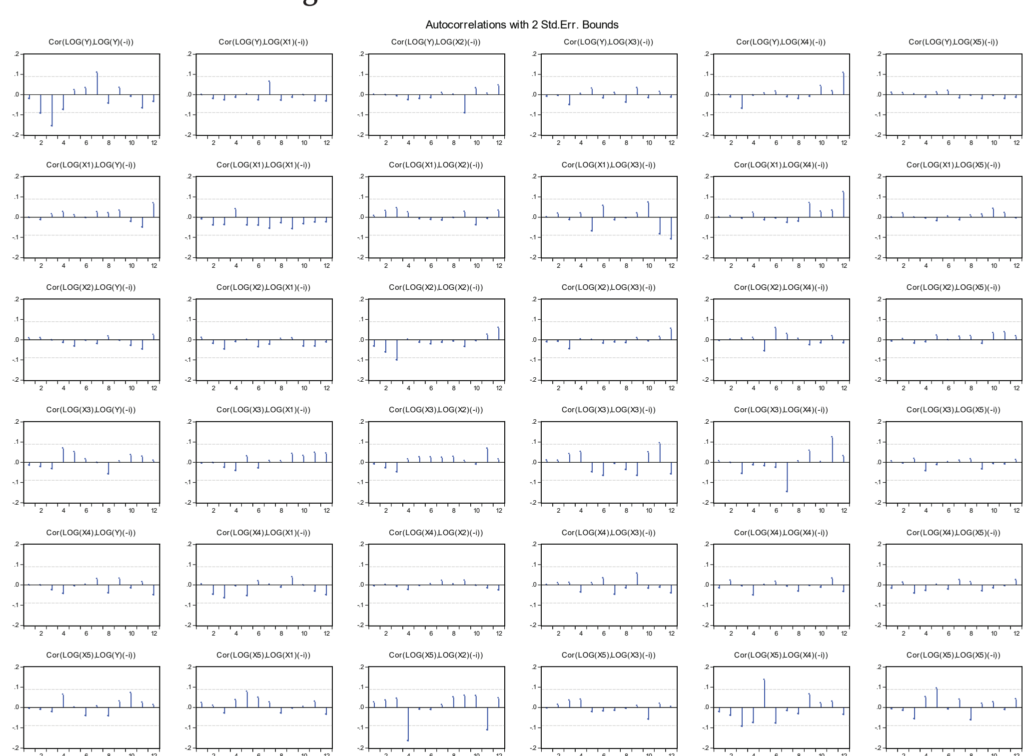
roots	*modulus*
1.000000	1.000000
1.000000	1.000000
1.000000	1.000000
1.000000	1.000000
1.000000	1.000000
–0.292093 + 0.400400*i*	0.495619
–0.292093 – 0.400400*i*	0.495619
–0.373831 + 0.309236*i*	0.485156
–0.373831 – 0.309236*i*	0.485156
–0.241553 – 0.415995*i*	0.481040
–0.241553 + 0.415995*i*	0.481040
0.461959	0.461959
–0.093514 – 0.337077*i*	0.349808
–0.093514 + 0.337077*i*	0.349808
0.180849 + 0.271276*i*	0.326032
0.180849 – 0.271276*i*	0.326032
–0.031385 + 0.296726*i*	0.298381
–0.031385 – 0.296726*i*	0.298381

Figure 1: Unit Circle



The residual test of VECM for correllogram confirms that there are autocorrelations among all the variables such as food grain production, GSDP, net irrigated area, fertilizer intake, cropping intensity and state fiscal deficit respectively. It is seen in Figure 2.

Figure 2: Auto-correlation of residuals



The VEC residual serial correlation LM test suggests that there are serial correlations among variables because LM stat with lag 1,lag 2 and lag 3 were computed as 62.428,77.908 and 76.854 respectively whose probabilities are less than 5% with null hypothesis of no serial correlation at lag.

Hansen -Doornik (1994) VEC residual normality test rejects H0= null hypothesis of residuals are multivariate normal since the Chi-square of Skewness and Kurtosis are rejected and probabilities of Jarque-Bera are also rejected at 5% level of significance. It is shown in Table 7. (Total observations=502, period-1990-91-2015-16)

Table 7: VEC Residual Normality test

component	skewness	chi-square	Degree of freedom	probability
1	–2.393634	189.1577	1	0.0000
2	–4.005192	309.6861	1	0.0000
3	–4.005192	320.1743	1	0.0000
4	–2.864513	227.3583	1	0.0000
5	–2.166972	169.7827	1	0.000
6	–2.621121	207.9519	1	0.0000
Joint		1424.111	6	0.0000
component	Kurtosis	chi-square	Degree of freedom	probability
1	19.74241	0.876503	1	0.3492
2	80.03112	856.8662	1	0.0000
3	93.13488	1244.985	1	0.0000
4	42.50402	428.4343	1	0.0000
5	29.02280	386.5760	1	0.0000
6	18.29044	67.10714	1	0.0000
Joint		2984.846	6	0.0000
component	Jarque-Bera	Degreeoffreedom	probability	
1	190.0342	2	0.0000	
2	1166.552	2	0.0000	
3	1565.160	2	0.0000	
4	655.7926	2	0.0000	
5	556.3587	2	0.0000	
6	275.0591	2	0.0000	
Joint	4408.957	12	0.0000	

Thus, the VECM is not normally distributed.

VEC residual heteroscedasticity test when there is no cross terms with 502 observations during the same period showed that the Chi-Square value of Joint test with 546 degree of freedom is found as 1605.446 whose probability is less than 5% ,so that there is heteroscedasticity problem in joint test without cross terms.

The impulse response functions indicate that VECM is non-stationary which implies that any shock to the variables does not tend the model towards equilibrium (Figure 3).

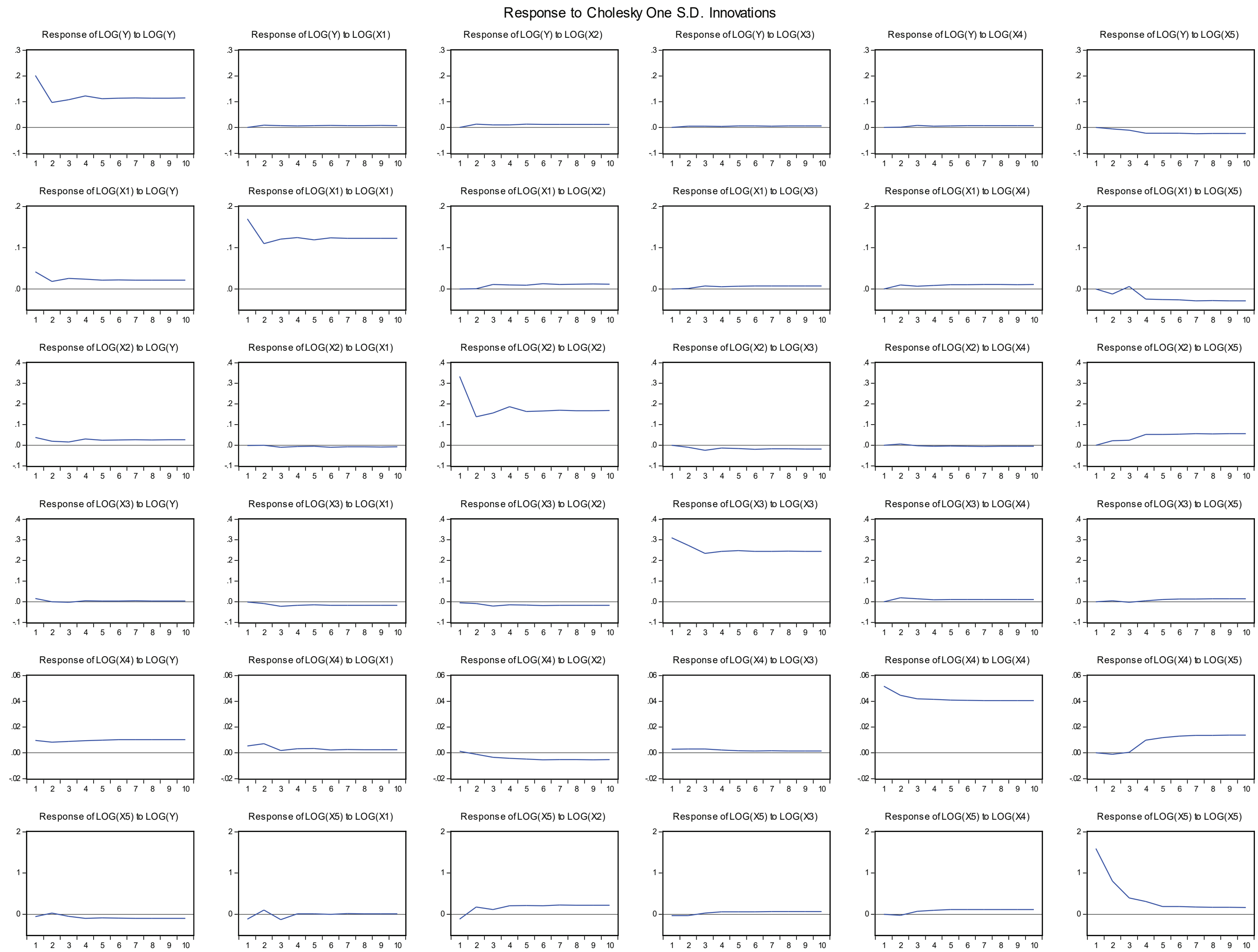


Figure 3: Impulse Response Functions

The co-integrating equation in the VECM states that there are significant long run causalities running from net irrigated area, utilization of fertilizers and cropping intensity of all the states in India to food grain production of Indian states during 1990-91-2015-16. It is convergent towards equilibrium insignificantly since t value of the coefficient of log(x_{1t-1}) is not significant at 5% level.

$$logY_{t-1} = 10.25000 - 0.187211 logx_{1t-1} - 0.974638 logx_{2t-1} - 0.242382 logx_{3t-1} - 2.027352 logx_{4t-1} + 0.633326 logx_{5t-1}$$
$$(-1.34) \qquad (-9.76)^{*} \qquad (-2.51)^{*} \qquad (-3.92)^{*} \qquad (10.28)$$
$$* = significant\ at\ 5\%\ level$$

In Figure 4, the instability of the co-integrating equation is plotted which is tending to equilibrium level insignificantly.

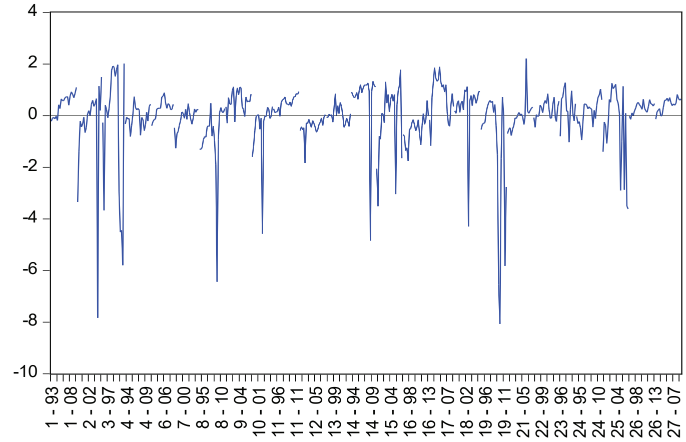


Figure 4 : Cointegrating Equation

Now in VECM, the paper verified whether there were long run and short causalities running from x_1, x_2, x_3, x_4, and x_5, on yi.e. causalities running from state domestic product, net irrigated area of state, fertilizer consumption of state, cropping intensity, and state fiscal deficit to food grain production respectively.

The estimated system equation [1] is given below taking 25 cross sections, 22 periods and 527 observations where food grain production is dependent and rest are independent variables.

$$\Delta log(y_t) = c(1)log(y_{t-1}) - 0.1872log(x_{1t-1}) - 0.974log(x_{2t-1}) - 0.242log(x_{3t-1})$$
$$-2.0273log(x_{4t-1}) + 0.6333log(x_{5t-1}) + 10.249 + c(2)\Delta log(y_{t-1}) + c(3)\Delta log(y_{t-2})$$
$$+c(4)\Delta log(x_{1t-1}) + c(5)\Delta log(x_{1t-2}) + c(6)\Delta log(x_{2t-1}) + c(7)\Delta log(x_{2t-2})$$
$$+c(8)\Delta log(x_{3t-1}) + c(9)\Delta log(x_{3t-2}) + c(10)\Delta log(x_{4t-1}) + c(11)\Delta log(x_{4t-2})$$
$$+c(12)\Delta log(x_{5t-1}) + c(13)\Delta log(x_{5t-2}) + c(14)$$

In Table 8, the values of coefficients, standard error, the t values and probabilities of the constants have been arranged.

Table 8: System equation 1

	coefficients	standard error	t statistic	probability
c(1)	−0.023507	0.009763	−2.407731	0.0164
c(2)	−0.520356	0.045472	−11.44334	0.0000
c(3)	−0.210590	0.045361	−4.642496	0.0000
c(4)	0.041784	0.052757	0.792012	0.4287
c(5)	0.025587	0.052880	0.483863	0.6287
c(6)	0.008331	0.027070	0.307776	0.7584
c(7)	0.008891	0.028829	0.308386	0.7589
c(8)	0.011792	0.028911	0.407886	0.6835
c(9)	−0.015201	0.029580	−0.513889	0.6076
c(10)	−0.018451	0.170306	−0.108339	0.9138
c(11)	0.067574	0.168955	0.399954	0.6894
c(12)	0.011306	0.006435	1.757007	0.0795
c(13)	0.007837	0.005798	1.351707	0.1771
c(14)	0.011875	0.012640	0.939539	0.3479

R^2=0.229675,F= 11.76 ,AIC=-0.354500,SC=-0.241140,*=significant at 5% level.*

The co-integrating equation (1) is estimated as:

$\Delta logy_t$=-0.023507$logy_{t-1}$-0.18721$logx_{1t-1}$-0.9746$logx_{2t-1}$-0.242381$logx_{3t-1}$-2.0273$logx_{4t-1}$ +0.6333$logx_{5t-1}$ +10.2499 where c(1) is negative(-0.023507) and significant(t=-2.407731),thus there are long run causalities running from x_1,x_2,x_3,x_4, and x_5 to y ,the speed of adjustment is 2.35% per annum, i.e. it is moving towards equilibrium although speed is very slow.

Again, there is no short run causality running from SDP to food grain production because the Wald test confirmed that χ^2(2)= 0.673942 (probability =0.71) and F(2,513) =0.336971 (probability = 0.71) so that null hypothesis of short run causality is accepted assuming c(4)=c(5)=0.

Secondly, assume C(6)=c(7)=0 in the Wald test, it is found that χ^2 (2)= 0.133969 (probability = 0.9352) and F(2,513)= 0.066985(probability=0.9352),so that there is no short run causality running from net irrigated area to food grain production.

Thirdly, there is no short run causality running from NPK consumption to food grain production because from the Wald test χ^2 (2)= 0.482635(probability= 0.78) and F(2,513)= 0.241317 whose probability is 0.78 so that null hypothesis of no short run causality is accepted assuming c(8)=c(9)=0.

Fourthly, there is no short run causality running from cropping intensity to food grain production since χ^2 (2)= 0.183655 (probability= 0.91) and F(2,513)= 0.091828 (probability= 0.91) so that null hypothesis of no short run causality is accepted assuming c(10)=c(11)=0 as observed from the Wald test.

Fifthly, the Wald test assured that there is no short run causality from state fiscal deficit to food grain production since χ^2 (2)= 3.458413 (probability = 0.17) and F(2,513)= 1.729207 whose probability is 0.17 so that null hypothesis of no short run causality is accepted assuming c(12)=c(13)=0.

Lastly, the residual test for normality, the value of Jarque-Bera =5149.736(probability =0.000) which means that the residuals of $\Delta logY_t$ is not normally distributed.

Moreover, residual cross section dependence test with null hypothesis of no cross section dependence (correlation) in residuals showed that Breusch –Pagan LM, Pesaran scaled LM and Pesaran CD statistic are 420.4335, 3.896055 and 7.901143 whose probabilities are 0.000 each (df=300) which means that there is cross section dependence in $\Delta logy_t$ In the Figure 3 of the impulse response function, the long and short causality from x_1,x_2,x_3,x_4, and x_5 to y have been shown in the figures of the first row.

Likewise, in VECM , the paper checked whether there are long run and short causalities running from x_2, x_3, x_4, x_5 and y to x_1 i.e. causality running from state domestic product, net irrigated area of state, fertilizer consumption of state, cropping intensity, and state fiscal deficit to food grain production respectively.

The estimated system equation-1 of the VECM-1 has been approaching towards equilibrium which is nicely plotted in Figure 5.

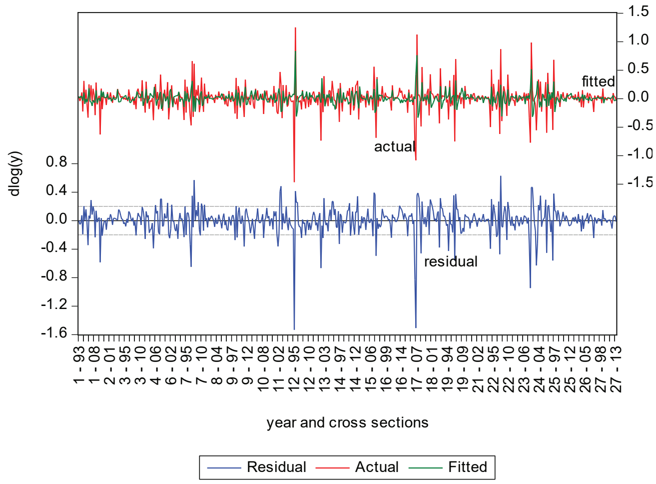


Figure 5: VECM 1 tends to equilibrium

The estimated system equation [2] is given below taking 25 cross sections, 22 periods and 524 observations where gross state domestic product is dependent and the rest are independent variables.

$$\Delta log(x_{1t}) = c(15)log(y_{t-1}) - 0.1872log(x_{1t-1}) - 0.974log(x_{2t-1}) - 0.242log(x_{3t-1})$$
$$-2.0273log(x_{4t-1}) + 0.6333log(x_{5t-1}) + 10.249 + c(16)\Delta log(y_{t-1}) + c(17)\Delta log(y_{t-2})$$
$$+c(18)\Delta log(x_{1t-1}) + c(19)\Delta log(x_{1t-2}) + c(20)\Delta log(x_{2t-1}) + c(21)\Delta log(x_{2t-2})$$
$$+c(22)\Delta log(x_{3t-1}) + c(23)\Delta log(x_{3t-2}) + c(24)\Delta log(x_{4t-1}) + c(25)\Delta log(x_{4t-2})$$
$$+c(26)\Delta log(x_{5t-1}) + c(27)\Delta log(x_{5t-2}) + c(28)$$

The values of coefficients, standard error, t statistic and probability are arranged in the Table 9.

Table 9: System equation-2

	coefficients	standard error	t statistic	probability
c(15)	–0.022991	0.008571	–2.682342	0.0075
c(16)	–0.022094	0.039300	–0.562177	0.5742
c(17)	0.004307	0.039208	0.109841	0.9126
c(18)	–0.368871	0.045608	–8.087895	0.0000
c(19)	–0.055450	0.045716	–1.212927	0.2257
c(20)	–0.026398	0.023419	–1.127215	0.2602
c(21)	0.013757	0.024919	0.552068	0.5811
c(22)	–0.003199	0.025142	–0.127232	0.8988
c(23)	0.004951	0.025652	0.192993	0.8470
c(24)	0.127847	0.147288	0.868010	0.3858
c(25)	–0.023703	0.146048	–0.162297	0.8711
c(26)	0.006640	0.005592	1.187574	0.2356
c(27)	0.017055	0.005027	3.392842	0.0007
c(28)	0.148449	0.010946	13.56226	0.0000

R^2=0.15 , F=7.036, SC=-0.532375, AIC=-0.646232

The co-integrating equation (2) is estimated as

$\Delta logx_{1t}$=-0.022991$logy_{t-1}$-0.1872$logx_{1t-1}$-0.9746$logx_{2t-1}$-0.2423$logx_{3t-1}$-2.0273$logx_{4t-1}$+0.633$logx_{5t-1}$+10.24 where c(15) is negative(-0.022991) and significant(t=-2.682342). Thus there are long run causalities running from y,x_2,x_3,x_4, and x_5 to x_1.The speed of adjustment is 2.29% per annum, i.e. it is moving towards equilibrium although speed is very slow.

Now it was found that there is no short run causality running from net irrigated area to SDP because the Wald test confirmed that χ^2 (2)= 2.535129 (probability=0.28) and F(2,510)= 1.267565 (probability = 0.28) so that null hypothesis of short run causality is rejected assuming c(20)= c(21)=0.

Secondly, there is no short run causality from NPK consumption to SDP because the Wald test confirmed that χ^2 (2)= 0.059754 (probability= 0.97) and F(2,510)= 0.029877 (probability= 0.97) so that null hypothesis of short run causality is rejected assuming c(22)= c(23)=0.

Thirdly, there is no short run causality from cropping intensity to SDP because the Wald test confirmed that χ^2 (2) = 0.821183(probability = 0.66) and F(2,510)= 0.410592(probability= 0.66) so that null hypothesis of short run causality is rejected assuming c(24)=c(25)=0.

Fourthly, there is short run causality running from state fiscal deficit to SDP because the Wald test confirmed that χ^2 (2) =11.70927 (probability= 0.00) and F(2,510)= 5.854636(probability = 0.00) so that null hypothesis of no short run causality is rejected assuming c(26)=c(27)=0. Similarly, there is no short run causality running from food grain production to SDP.

Finally, the residual test for normality suggested that Jarque-Bera is found as 125916 whose probability=0.00, therefore it is not normally distributed. And residual cross section dependence test with null hypothesis of no cross section dependence (correlation) in residuals showed that Breusch –Pagan LM, Pesaran scaled LM and Pesaran CD statistic are 488.7362, 6.684502, 9.739658 whose probabilities are 0.000 each (df=300) which means that there is cross section dependence in $\Delta logx_{1t.}$In the Figure 3 of the impulse response function, the long and short causality from y,x_2,x_3,x_4 and x_5 to x_1 have been shown in the figures of the second row.

From VECM the estimated system equation [3] is given below taking 25 cross sections, 21 periods and 507 observations where net irrigated area is dependent and the rest are independent variables.

$$\Delta log(x_{2t}) = c(29)log(y_{t-1}) - 0.1872log(x_{1t-1}) - 0.974log(x_{2t-1}) - 0.242log(x_{3t-1}) - 2.0273log(x_{4t-1}) + 0.6333log(x_{5t-1}) + 10.249 + c(30)\Delta log(y_{t-1}) + c(31)\Delta log(y_{t-2}) + c(32)\Delta log(x_{1t-1}) + c(33)\Delta log(x_{1t-2}) + c(34)\Delta log(x_{2t-1}) + c(35)\Delta log(x_{2t-2}) + c(36)\Delta log(x_{3t-1}) + c(37)\Delta log(x_{3t-2}) + c(38)\Delta log(x_{4t-1}) + c(39)\Delta log(x_{4t-2}) + c(40)\Delta log(x_{5t-1}) + c(41)\Delta log(x_{5t-2}) + c(42)$$

The values of coefficients, standard error, t statistic and probability are arranged in the Table 10.

Table 10: System equation-3

	coefficients	Standard Error	t statistic	probability
$c(29)$	0.054370	0.016980	3.201994	0.0015
$c(30)$	–0.044297	0.076985	–0.575395	0.5653
$c(31)$	–0.044080	0.077664	–0.567565	0.5706
$c(32)$	0.005534	0.089213	0.062031	0.9506
$c(33)$	–0.049774	0.089584	–0.55561	0.5787
$c(34)$	–0.570680	0.047902	–11.91342	0.0000
$c(35)$	–0.258351	0.049027	–5.269576	0.0000
$c(36)$	–0.021708	0.050226	–0.432210	0.6658
$c(37)$	–0.045990	0.050346	–0.913476	0.3614
$c(38)$	0.239176	0.288168	0.829990	0.4069
$c(39)$	0.037284	0.284807	0.130911	0.8959
$c(40)$	–0.021266	0.011361	–1.871786	0.0618
$c(41)$	–0.017237	0.010079	–1.710133	0.0879
$c(42)$	0.027304	0.021438	1.273623	0.2034

R^2=0.27 , F=15.54, SC=0.803576, AIC=0.686813,*=significant at 5% level*

The co-integrating equation -3 is observed as below.

$\Delta logx_{2t}=0.054370logy_{t-1}-0.1872logx_{1t-1}-0.9746logx_{2t-1}-0.242logx_{3t-1}-2.0273logx_{4t-1}+0.633logx_{5t-1}+10.249$

Since, c (29) is positive (0.054370) and significant (t=3.201994), thus there are no long run causalities running from y, x_1, x_3, x_4 and x_5 to x_2 ,the speed of adjustment is 5.43% per annum, i.e. it is not moving towards equilibrium.

If c (30) = c (31) = 0, then the Chi-square (2) = 0.4573 (p = 0.795),i.e., there is no short run causality from food grain production to net irrigated area. If c(32)=c(33)=0,then the Chi-square(2)=0.3859 (p=0.8245), i.e., there is no short run causality running from SDP to net irrigated area.

Now it was found that there is no short run causality running from NPK consumption to net irrigated area because the Wald test confirmed that χ^2 (2)= 0.939254(probability=0.62) and F(2,510) = 0.469627(probability=0.62) so that null hypothesis of no short run causality is accepted assuming c(36)=c(37)=0.

Again, there is no short run causality running from cropping intensity to net irrigated area because the Wald test confirmed that χ^2 (2) = 0.690381(probability = 0.70) and F(2,510) = 0.345191 (probability = 0.70) so that null hypothesis of no short run causality is accepted assuming c(38)=c(39)=0.

Even, there is no short run causality running from state fiscal deficit to net irrigated area because the Wald test confirmed that the χ^2 (2)= 4.343150 (probability =0.11) and F(2,493)= 0.1151(probability =0.11) so that null hypothesis of no short run causality is accepted assuming c(40)=c(41)=0. Similarly, there is no short run causality running from food grain production and SDP to net irrigated area.

The residual test for normality suggested that Jarque-Bera is found as 167228.4 whose probability=0.00, therefore it is not normally distributed. And the residual cross section dependence test with null hypothesis of no cross section dependence (correlation) in residuals showed that Breusch –Pagan LM, Pesaran scaled LM and Pesaran CD statistic are 405.4497, 3.284344, 0.915779 whose probabilities are 0.000 for first two and 0.3598 for third (df=300) which imply that there is cross section dependence in $\Delta logx_{2t.}$In the Figure 3 of the impulse response function, the long and short causalities from y, x_1, x_3, x_4 and x_5 to x_2 have been shown in the figures of the third row.

From the VECM the estimated system equation [5] is given below taking 25 cross sections, 22 periods and 510 observations where cropping intensity is the target variable and the rest are independent variables.

$$\Delta log(x_{4t}) = c(57)log(y_{t-1}) - 0.1872log(x_{1t-1}) - 0.974log(x_{2t-1}) - 0.242log(x_{3t-1}) - 2.0273log(x_{4t-1}) + 0.6333log(x_{5t-1}) + 10.249 + c(58)\Delta log(y_{t-1}) + c(59)\Delta log(y_{t-2}) + c(60)\Delta log(x_{1t-1}) + c(61)\Delta log(x_{1t-2}) + c(62)\Delta log(x_{2t-1}) + c(63)\Delta log(x_{2t-2}) + c(64)\Delta log(x_{3t-1}) + c(65)\Delta log(x_{3t-2}) + c(66)\Delta log(x_{4t-1}) + c(67)\Delta log(x_{4t-2}) + c(68)\Delta log(x_{5t-1}) + c(69)\Delta log(x_{5t-2}) + c(70)$$

The values of coefficients, standard error, t statistic and probability are arranged in the Table11.

Table 11: System equation-5

	coefficients	stadard error	t statistic	probability
$c(57)$	0.009464	0.002677	3.535668	0.0004
$c(58)$	–0.011145	0.012127	–0.919011	0.3585
$c(59)$	0.005001	0.012134	0.412158	0.6804
$c(60)$	0.016951	0.014084	1.203557	0.2293
$c(61)$	–0.019162	0.014073	–1.361618	0.1739
$c(62)$	0.001886	0.007923	0.238034	0.8120
$c(63)$	0.001884	0.007812	–0.151602	0.8796
$c(64)$	0.002126	0.007926	0.268195	0.7887
$c(65)$	–0.011821	0.007933	–1.490156	0.1368
$c(66)$	–0.115137	0.045518	–2.529499	0.0117
$c(67)$	–0.057478	0.044975	–1.277980	0.2019
$c(68)$	–0.006382	0.001770	–3.605764	0.0003
$c(69)$	–0.004778	0.001582	–3.020328	0.0027
$c(70)$	0.002155	0.003390	0.635581	0.5253

R^2=0.066562, F=2.720676 , SC=-2.887674 , AIC=-3.003912, *=significant at 5% level*

The co-integrating equation-4 is found as:

$\Delta logx_{4t}$=0.009464$logy_{t-1}$-0.1872$logx_{1t-1}$-0.9746$logx_{2t-1}$-0.2423$logx_{3t-1}$-2.027$logx_{4t-1}$+0.633$logx_{5t-1}$+10.249

Here, C(57) is positive (0.009464) but significant (t=3.535668), so there are no long run causalities running from x_1,x_2,x_3,x_5 and y to x_4 respectively. Thus the system does not move to equilibrium but its divergence is significant.

If c(58)=c(59)=0, then the Chi-square (2) = 1.6447 (p=0.4394) which is accepted as no causality, i.e. there is no short run causality from food grain production to cropping intensity. If c(60)= c(61)=0, then the Chi-square(2)=5.10912(p=0.077),i.e. there is no short run causality from SDP to cropping intensity. If c(62)=c(63)=0,then the Chi-square(2)=0.1411(p=0.931),i.e. there is no short run causality from net irrigated area to cropping intensity. Now, if c(64)=c(65)=0,then the Chi-square(2)=2.4216 (p=0.298),i.e., there is no short run causality from NPK consumption to cropping intensity.

Now it was found that there is short run causality running from state fiscal deficit to cropping intensity because the Wald test confirmed that the χ^2 (2)=15.04988 whose probability is 0.00 and F(2,496)= 7.524939 whose probability is 0.00 so that null hypothesis of no short run causality is rejected assuming c(68)=c(69)=0.In a similar way, it was found that there are no short run causalities running from food grain production, SDP, net irrigated area, NPK consumption to cropping intensity.

Lastly, the residual test for normality suggested that Jarque-Bera is found as 12285.87 whose probability=0.00, therefore, it is not normally distributed. And residual cross section dependence test with null hypothesis of no cross section dependence (correlation) in residuals showed that Breusch –Pagan LM, Pesaran scaled LM and Pesaran CD statistic are 361.2106, 1.478294, 0.638147 whose probabilities are 0.000 , 0.1393 and 0.5234 respectively (df=300) which means that there is cross section dependence in $\Delta logx_{4t.}$In the Figure 3 of the impulse response function, the long and short causalities from y,x_1,x_2,x_3 and x_5 to x_4 have been shown in the figures of the 5th row.

Therefore, the paper proved that there are four co-integrating equations where $\Delta logy_t$ and $\Delta logx_{1t}$ have long run causalities and they are moving towards equilibrium with slow speed but $\Delta logx_{2t}$ and $\Delta logx_{4t}$ do not move to equilibrium level because they have no long run causalities with the independent variables. On the other hand, there are short run causalities running from state fiscal deficit to SDP and cropping intensity only but other variables do not show any short run causality.

Limitations and future scope of research

There are several limitations of this model because author does not include environmental variables, agricultural credits of each state, labor employed in the production, and other infrastructural factors which could affect food grain production. The model could use political and social factors, educational level and foreign direct investment as dummy variables to explain variation of food grain production. State intervention might be judged through SDP and fiscal deficit of the states. Therefore, the model has enough scope for extending its independent or dummy variables to explain further in the offing. The paper does not include other two co-integrating equations along with their estimated VECM equations. It is left for further research. Even, the Kao (1999) and the Pedroni(1999) models for panel cointegration test were not computed to compare the results with Fisher-Johansen cointegration model.

Suggested policies

For rice production in India, several improved land and crop management practices and reducing environmental impacts, including more efficient irrigation, direct seeding, improved fertilization and effective weed control can raise yields. Several reduced tillage management options to help conserve soils in Indian rice-wheat cropping systems have been developed and are increasingly used while the rising costs of irrigation are already driving shifts from irrigated rice towards other more water-efficient food crops.

Improved water management including proper soil preparation, crop selection and timing of planting to reduce runoff and utilize available water resources even in the absence of the irrigation are important policies for implementation. Efforts to overcome water constraints on crop production in smallholder systems include irrigation and other water management practices, and the use of diverse and drought resistant varieties, are required (Pretty et al, 2006).

Improved soil management, promoting the use of crop rotations, intercropping with leguminous species, may reduce tillage and incorporate agricultural residues. Minimal tillage and the retention of crop residues in particular can often reduce soil erosion, reduce GHGs and support soil fertility, and may raise yields (Hobbs et al, 2008).

Improved pest (including disease and weed) management through integrated pest management (IPM), relying primarily on interventions supporting crop health and discouraging pest outbreaks have seen growing effectiveness and acceptance among farmers(Khan et al,2011).

Good practices to manage environmental impacts, intercropping and the incorporation of crop residues into soils after harvest to maintain soil fertility, using of clean planting material to manage viral diseases , better storage of roots in the soil, improved harvest and storage practices and improved processing methods are especially useful to reduce post-harvest losses with cassava(Legg et al,2014).

Food Crop Act, Land use Act, Intensive Schemes for paddy, cotton and oilseed should bring sharply into focus the possibility of changing crop pattern in India. The revamp of National Food Security Mission, Monitoring and Evaluation of all projects at national level, reform funding patterns, bringing green revolution to Eastern India and more emphasis on diversification programmes are the key policy issues in India to grow more food grain production.

On the macro variables concerned, reduction of state fiscal deficit, convergence of SDP in agriculture, stability in the wholesale price index of agricultural commodities, increase in crop loan and insurance ,agricultural credit and minimum support prices should be given prior importance. A greater infrastructure in agriculture might boost agricultural production which will enhance the share of agriculture in state domestic product.

Conclusion

The paper concludes that one per cent increase in SDP at current prices, net irrigated area, NPK used, cropping intensity, state fiscal deficit and state gross capital formation per year led to 0.177 %, 0.7066%, 0.0578% and 1.5099%, increase in food grain production per year respectively and decrease of 0.0599% and 0.0159% food grain production per year from 1990-91 to 2015-16 in 27 Indian states in fixed effect panel regression model. Johansen-Fisher panel cointegration test confirmed that Max Eigen statistic contains three co-integrating equations in and Trace statistic contains four cointegrating equations. It means that there is significant long run association with food grain production of Indian states from state net irrigated area, utilization of fertilizers of the states, cropping intensity of the states during 1990-91-2015-16.VECM is stable, non-normal distribution and non-stationary having problem of autocorrelation. In co-integrating equations change of food grain production and change of SDP have long run causality and they are moving towards equilibrium with slow speed of adjustment but change of net irrigated area and change of cropping intensity do not move to equilibrium level because they have no long run causalities with the independent variables. On the other hand, there are short run causalities running from state fiscal deficit to SDP and cropping intensity only but the rest of the variables do not show any short run causality.

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