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Growth and instability analysis in Indian agriculture

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Abstract
Agricultural growth and instability has remained subject of intense debate in the agricultural economics literature in India. Instability is a very essential characteristic of agriculture. Since agriculture is dependent on weather conditions, the area, production and yield of the crops are subject to significant variations over time. This study aims at studying the growth and instability in the major crops of India. Cuddy Della Valle Index and Coppock's instability index has been calculated for all the crops. The entire study period is divided into three sub-periods: 1990-91 to 1999-2000, 2000-01 to 2009-10 and 2009-10 to 2016-17. Several fluctuations in the growth pattern of area, production and productivity of the crops were observed in the study. Also, different pattern of instability were observed in the area, production and productivity of the crops over the period.

Keywords: Cuddy Della Valle index, Coppock's instability index, growth and instability

1. Introduction

Agriculture is an important part of Indian economy. It provides source of livelihood for around 70 per cent of the population. It contributes to 18 per cent of Gross Domestic Product of the economy. It is an important source of raw material for many agro-based industries. India's geographical condition is unique for agriculture because it provides many favourable conditions. There are plain areas, fertile soil, long growing season and wide variation in climatic condition etc. Also, India has been making sincere efforts by using science and technology to increase production. Gross Value Added by agriculture, forestry and fishing is estimated at Rs 17.67 trillion (US$ 274.73 billion) in financial year 2018. Indian agriculture is dominated by the cultivation of food grains which occupy 76% of the total cropped area and account for 80% of the total agricultural production of the country. These cereals include rice, wheat, millet, gram, maize and pulses which are grown to meet the food requirements of India's vast population. Agriculture is considered as backbone of the economy. This is because it contributes to economic development in at least four ways: product contribution i.e. making available food and raw materials; market contribution i.e. providing market for goods produced by other sectors; factor contribution i.e. making available labour and capital to the non-agricultural sector and it also leads to foreign exchange earnings from the export of agricultural items. Indian agriculture is mostly dependent on rainfall whose variability in time and place has adverse effect on agricultural output. It is really a matter of concern that despite five decades of constant endeavor only 41.2% of the total cropped area has been brought under irrigation. Rest is at the mercy of rain-god. That is why when rain fails agricultural production is badly affected, scarcity prevails and prices reach sky high. If the entire agricultural area is brought under irrigation agricultural production may be easily doubled.

Agriculture growth and instability has remained subject of intense debate in the agricultural economics literature in India. While the need for increasing agricultural production or growth is obvious, the increase in instability in agricultural production is considered adverse for several reasons. It raises the risk involved in farm production and affects farmers' income and decisions to adopt high paying technologies and make investments in farming. Instability in production affects price stability and the consumers, and it increases vulnerability of low income households to market. Instability in agricultural and food production is also important for food management and macroeconomic stability (Chand and Raju, 2009) [11]. Instability in agricultural production is on the rise due to several factors such as erratic rainfall pattern, low irrigation coverage, and increase in frequency and severity of natural disasters.

Instability is a very essential characteristic of agriculture. Since agriculture is dependent on weather conditions, the area, production and yield of the crops are subject to significant variations over time. This study aims at studying the growth and instability in eight principal crops of India. These crops are selected because they are of utmost importance for the country.

Rice

Rice production in India is an important part of the national economy. India is the world's 2nd largest producer with approximately 43 Mio Ha planted area, accounting for 22% of the world's rice production. Rice is a basic food crop and being a tropical plant, it flourishes in hot and humid climate. It is grown in assured irrigated areas and in rain fed areas that receive assured annual rainfall. Hence, it can be grown in both Kharif & Rabi seasons.

Wheat
After rice, wheat is the second most important food-crop grown in India and it is the staple diet for millions of Indians, mainly in the north and north-western parts of the country. Wheat is the main source of protein, carbohydrate and vitamin for people in the rural areas. India is the fourth largest producer of wheat in the world after Russia, the USA and China and accounts for 8.7 per cent of the world's total production of wheat.

Maize
Maize is one of the most crucial cereals produced in different parts of the world under diverse climatic and ecological conditions. Due to its increasing importance, maize has become a major staple and cash crop for smallholder farmers around the developing world. In India, maize is emerging as the third most important crop, after rice and wheat. Maize was traditionally grown as staple food, primarily for household consumption, but its demand for feed and industrial uses has increased rapidly in the recent past.

Sugarcane
Sugarcane is an important commercial crop of the country occupying around 3.8 million hectares of land with an annual cane production of around 270 million tonnes. That is, it occupies about 2.8% of the cultivated land area and contributes about 7.5 % to the agricultural production in the country. There are 35 million farmers growing sugarcane and another 50 million depend on employment generated by the 571 sugar factories and other related industries using sugar.

Pulses
Pulses are a very important crop for India. They are an important source of protein, grow quickly, generate good profits for farmers, and contribute to agricultural and environmental sustainability. It is second important constituent of Indian diet after cereals. India is the largest producer (25% of global production), consumer (27% of world consumption) and importer (14%) of pulses in the world. Pulses account for around 20 per cent of the area under foodgrains and contribute around 7-10 per cent of the total foodgrains production in the country.

Cotton
Cotton is one of the most important fiber and cash crop of India and plays a dominant role in the industrial and agricultural economy of the country. It provides the basic raw material (cotton fibre) to cotton textile industry. Cotton in India provides direct livelihood to 6 million farmers and about 40 -50 million people are employed in cotton trade and its processing.

Oilseeds
India is one of the largest producers of oilseeds in the world and occupies an important position in the Indian agricultural economy. It is estimated that nine oilseeds namely groundnut, rapeseed-mustard, soybean, sunflower, safflower, sesame, niger, castor and linseed, accounted for an area of 23.44 million hectares with the production of 25.14 million tonnes.

Fruits
Fruit growing is one of the important and age old practices, practiced in India since ancient times. India is the largest producer of Fruits in the world and is known as fruit basket of world. India is also a major exporter of fruits to the world. The country has exported 326515.56 MT of fresh fruits other than Grapes and Mango to the world for the worth of Rs. 1573.26 crores/ 244.15 USD Millions during the year 2017-18.

2. Review of literature
Ramesh Chand and S S Raju (2008) [11] have also studied the instability in agriculture sector of Andhra Pradesh in a disaggregated manner. In a large state like Andhra Pradesh, the instability measured by state level data varies greatly from those at the disaggregated level. Thus, state level analysis does not give complete picture of shocks in agricultural production which underestimates shocks in farm income.

Elamin *et al.* (2011) [9] have tried to measure the extent of instability and contribution of different components to change in mean production of main crops grown in Gezira scheme.it was found that Sorghum, wheat and cotton have witnessed a continuous increase in instability over the two periods and there was decrease in instability of groundnut during post-liberalisation period. It was found that instability in area and yield of all the crops followed the same direction. Rehabilitation of irrigation canals, strong agricultural research and extension were suggested to help achieve stability in agricultural production.

Anjani Kumar and Rajni Jain (2013) [8] have studied the trends in growth and instability in Indian agriculture at the district level. Large variations were observed in the productivity of crop sector within the state and for the country as a whole. The data analysis emphasised the important role of modern inputs in increasing the productivity of crop sector such as fertilisers, rainfall, irrigation, human resource and transportation.

Pichad *et al.* (2014) [10] have studied the growth and instability in area, production and productivity of Chickpea in Amravati district. Compound Annual Growth Rate and Coefficient of Variation were used for the analysis. The results revealed that compound growth rates for area, production and productivity for period II were found positive and significant. The coefficient of variation indicated that instability in Chickpea area exhibited less variation than production and productivity at overall period whereas; production witnessed highest instability as compared to area and productivity at overall period.

Ayalew and Sekar (2016) [3] have studied the trends and regional disparity of maize production in India. Compound Annual Growth Rate, Cuddy Della Valle Index and decomposition analysis were used to examine the data ranging from 1980 to 1981 and 2011 to 2012. The study found an increase in the area and production of maize during the period. Such increase was possible due to increase in yield. The study found that maize performed better in Andhra Pradesh, Bihar, Gujarat, MP, Rajasthan and Uttar Pradesh as increase in yield is coupled with decline in instability due to the adoption of modern varieties of maize.

Harshita Tewari etal (2017) [6] have analysed the growth and

instability in area, production and productivity of wheat in Uttar Pradesh. Cuddy Della Valle Index and Decomposition analysis were done for the period 1990-91 to 2013-14. The highest productivity was found in western region and lowest in Bundelkhand region. Also, there was high instability in production and productivity as compared to area under wheat and yield effect was found to be the dominant in the growth of production.

Going through the above literature, it is found that the earlier studies have either covered single crop or have been done for smaller period. This study has attempted to cover major crops of India for a larger period of time.

3. Objective of the study

The objective of the study is to study the growth and instability in area, production and productivity of major crops in India.

4. Hypothesis of the study

Null Hypothesis H_0: There has been no instability in the area, production and productivity of major crops over the years.

Alternative hypothesis H_1: There has been instability in the area, production and productivity of major crops over the years.

Sub-Hypotheses

The study would test the following null sub-hypotheses against their alternative:

H_{01}: There has been no instability in the area of major crops over the years.

H_{02}: There has been no instability in the production of major crops over the years.

H_{03}: There has been no instability in the productivity of major crops over the years.

5. Data and Methodology

The study is based on secondary data collected from various published sources. Data on area, production, and yield of the crops were collected from Directorate of Economics and Statistics, Ministry of Agriculture, Government of India and indiastat.com.

Estimation of growth rates

The growth rate was estimated using exponential trend model (Veena, 1996) [13].

$$Y = a.\ b^t$$

where,

Y =Area/production/productivity

a = Intercept

b = Regression co-efficient

t = Time variable.

The above equation can also be written as,

$$Log\ Y = Log\ a + Log\ b$$

From the estimated function the compound growth rate was worked out by:

$$CAGR\ (r) = [Antilog\ (log\ b) - 1] \times 100$$

where,

r = compound growth rate.

The agricultural instability can be measured by different methods, such as the coefficient of variation (CV), dispersion, Cuddy Della Valle Index (CDI), Coppock Instability index, etc. The present study applies the Cuddy Della Valle Index and Coppock instability index for measuring the instability. Cuddy Della Valle index first de-trends the given series and gives a clear direction about the instability. The use of coefficient of variation as a measure to show the instability in any time series data has some limitation. If the time series data exhibit any trend, the variation measured by CV can be over-estimated, i.e. the region which has growing production are at constant rate will score high in instability of production if CV is applied for measuring instability. As against that, Cuddy-Della Valle index attempts to de-trend the CV by using coefficient of determination ($\bar{R}^2$). Thus it is a better measure to capture instability in agricultural production. A low value of this index indicates the low instability in farm production and vice-versa. CDVI was originally developed by Cuddy and Valle (1978) for measuring the instability in time series data that is characterized by trend. The estimable form of the equation is as follows:

$$CDVI = CV \times \sqrt{1 - \bar{R}^2}$$

Where CV is the coefficient of variation in percent, and $\bar{R}^2$ is the coefficient of determination from time trend regression adjusted by the number of degree of freedom.

Apart from Cuddy Della Valle Index, this study also calculated Coppock instability index.

$$Coppock's\ instability\ index = Antilog\ \left(\sqrt{V\ log} - 1\right) \times 100$$

Where,

$$V\ log = \frac{\sum(log\frac{X_{t+1}}{X_t} - m)^2}{n}$$

X_t= Area/Production/Yield

t = number of years

m = mean of the difference between logs of X_{t+1}, X_t

Log V = Logarithmic variance of the series

6. Results and Discussions

6.1 Growth trends and instability in the area of principal crops

In this sub-section, compound annual growth rates of area of 8 major principal crops in India over three periods of time from 1990-91 to 2016-17 have been examined and are presented in table 1.

Table 1: CAGR of the area under the crops

Crops	1990-91 to 1999-2000	2000-01 to 2009-10	2009-10 to 2016-17
Rice	0.0062	-0.0071	0.0043
Wheat	0.0144	0.0112	0.0096
Maize	0.0093	0.0250	0.0200
Sugarcane	0.1514	-0.0036	0.0020
Pulses	-0.0171	0.0150	0.0183
Cotton	0.0176	0.0192	-0.0061
Oilseeds	0.0005	0.0146	-0.0065
Fruits	0.0354	0.0562	-0.0002

***Source*:** Author's calculation

The annual growth rate of the area under rice was 0.0062 percent during the first sub-period. The figure fell to -0.0071 in the second period and then increased to 0.0043 per annum in the third sub-period. The growth rate of area under wheat has shown continuous decline throughout the entire period. For maize, there was increase in the growth rate in the second sub-period but it fell down in the third sub-period. The growth rate of area under sugarcane fell negative in the second sub-period but increased to 0.002 per cent in third period. Area under pulses has increased throughout the entire period. The area under cotton, oilseeds and fruits has increased in second sub-period but in the third period, the growth rates of the three crops were negative.

Table 2: Instability in the area under the crops

Crops	1990-91 to 1999-2000	2000-01 to 2009-10	2009-10 to 2016-17
Rice	1.3535	3.5569	0.5862
Wheat	2.0690	2.0024	1.6728
Maize	1.3779	2.3783	2.7263
Sugarcane	4.6332	9.9888	3.5777
Pulses	3.8553	4.1421	8.4727
Cotton	5.4183	6.9317	6.2064
Oilseeds	3.6499	6.5059	3.0575
Fruits	9.8594	5.2229	6.2789
CV	69.28265	52.25771	65.48672

***Source*:** Author's calculation

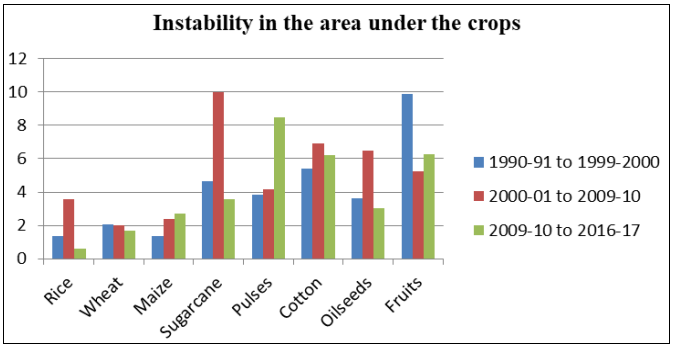

Fig 1

The instability in the area under rice, maize, sugarcane, pulses, cotton and oilseeds have increased in the second sub-period and it continued to increase further for maize and pulses but it declined for the remaining crops. For wheat, there has been continuous decline in the instability over the period and for fruits, the instability declined in the second sub-period but again increased in the third sub-period. Considering the area of all the crops over time, we found that the instability has first declined and then it increased. The first null hypothesis is rejected since there is instability in the area of the crops.

6.2 Growth trends and instability in the production of principal crops

Growth in total agricultural production over a period of time indicates the speed of agricultural development in the state. During the first time period, among the 8 principal crops, fruits followed by wheat have shown the highest growth of production per annum. From period II onwards, sugarcane accounted deceleration in production and shows negative compound growth rate during these periods.

Table 3: CAGR of the production of the crops

Crops	1990-91 to 1999-2000	2000-01 to 2009-10	2009-10 to 2016-17
Rice	0.0211	0.0052	0.0225
Wheat	0.0368	0.0165	0.0211
Maize	0.0281	0.0371	0.029
Sugarcane	0.0243	-0.0013	-0.019
Pulses	-0.0067	0.0316	0.0403
Cotton	0.0177	0.1083	-0.0021
Oilseeds	0.0119	0.0338	-0.0062
Fruits	0.0465	0.0635	-0.1324

***Source*:** Author's calculation

The annual growth rate of production of rice and wheat has declined in the second sub-period and then increased in the third period. For maize, the growth rate first increased and then declined. For pulses, there was continuous improvement in the growth rates over the period. The growth rates for cotton, oilseeds and fruits have increased in the second sub-period but it again declined in the third period.

Table 4: Instability in the production of the crops

Crops	1990-91 to 1999-2000	2000-01 to 2009-10	2009-10 to 2016-17
Rice	3.1184	7.9969	3.0454
Wheat	3.3743	4.8541	4.9076
Maize	6.2007	9.9892	4.5589
Sugarcane	5.5630	13.7336	5.3687
Pulses	6.7876	7.6143	12.3798
Cotton	10.2615	14.4199	5.8652
Oilseeds	6.6091	14.4427	8.8911
Fruits	6.3709	3.5974	25.8378
CV	36.89271	44.80341	84.24655

***Source*:** Author's calculation

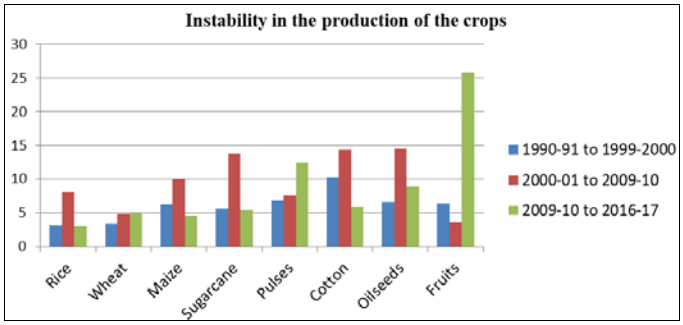

Fig 2

The instability in the production of all the crops except fruits has increased in the period II as compared to period I. It further increased for wheat and pulses but declined for others. For fruits, the instability has declined in the second sub-period but increased again in the third period. Also, the instability in the production of all the crops has increased throughout the period. Finding such instability in the production of the crops, we have rejected our second null hypothesis.

6.3 Growth trends and instability in the productivity of principal crops

Table 5 shows the rate of growth of productivity of 8 principal crops in India during different time periods.

Table 5: CAGR of the productivity of the crops

Crops	1990-91 to 1999-2000	2000-01 to 2009-10	2009-10 to 2016-17
Rice	0.0148	0.0125	0.0181
Wheat	0.0221	0.0052	0.0114
Maize	0.0186	0.0117	0.0095
Sugarcane	0.0090	0.0022	-0.0221
Pulses	0.0105	000164	0.0217
Cotton	0	0.0871	0.0042
Oilseeds	0.1142	0.0188	0.0002
Fruits	0.0116	0.0099	0.0420

***Source*:** Author's calculation

As far as annual growth rate of productivity of the crops are concerned, it declined in the second period for rice, wheat, maize, sugarcane, pulses and fruits and continued to fall further for maize and sugarcane. However, the growth rate improved for rice, wheat, pulses and fruits. The growth rate of cotton and oilseeds have increased in the second period but fell down in the third period.

Table 6: Instability in the productivity of the crops

Crops	1990-91 to 1999-2000	2000-01 to 2009-10	2009-10 to 2016-17
Rice	2.5945	5.3131	2.7070
Wheat	6.6352	3.3931	5.5771
Maize	5.9173	9.0064	2.3540
Sugarcane	2.7973	4.9937	3.0589
Pulses	5.1774	4.7140	7.6405
Cotton	8.7908	14.4437	7.3394
Oilseeds	4.9367	11.6028	7.2949
Fruits	8.6510	6.0849	3.5819
CV	41.02355	52.02531	45.9043

***Source*:** Author's calculation

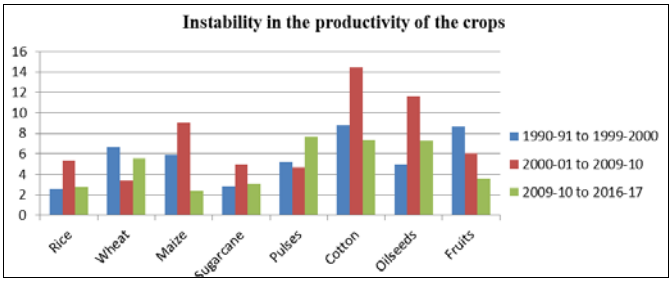

Fig 3

The instability in productivity has increased for rice, maize, sugarcane, cotton and oilseeds in the second period and then declined in the third period. On the other hand, the instability in the productivity of wheat and pulses have declined in the second period but increased in the third period and for fruits, the instability continued to decline throughout the period. Taking the productivity of all the crops over time, we found that the instability has increased in the second period and then declined in the third sub-period. The third null hypothesis is also rejected since there is instability in the productivity of the crops.

6.4 Coppock's Instability index

Having calculated Cuddy Della Valle index for the area, production and productivity of the principal crops for the three sub-periods, we will now compute the Coppock's instability index for the same.

Table 7: Instability in the area under the crops

Crops	1990-91 to 1999-2000	2000-01 to 2009-10	2009-10 to 2016-17
Rice	0.008	0.088	0.019
Wheat	0.038	0.039	0.011
Maize	0.022	0.038	0.075
Sugarcane	0.159	0.536	0.055
Pulses	0.098	0.187	0.353
Cotton	0.154	0.300	0.215
Oilseeds	0.097	0.194	0.094
Fruits	0.794	0.204	0.246
CV	150.63	82.62	92.49

***Source*:** Author's calculation

Instability in the area for rice, wheat and cotton have increased in the second sub-period but declined in the third period. For maize and sugarcane, there is continuous increase in the instability throughout the period. The instability in the area for

pulses, oilseeds and fruits has first decreased and then again it increased in the third period. For the entire crops as a whole, the instability in the area has first declined and then increases in the third period.

Table 8: Instability in the production of the crops

Crops	1990-91 to 1999-2000	2000-01 to 2009-10	2009-10 to 2016-17
Rice	0.083	0.718	0.061
Wheat	0.132	0.168	0.180
Maize	0.385	0.953	0.192
Sugarcane	0.219	0.819	0.151
Pulses	0.477	0.812	1.006
Cotton	0.710	1.352	0.268
Oilseeds	0.365	2.396	0.693
Fruits	0.154	0.091	7.44
CV	66.90	79.37	201.97

***Source*:** Author's calculation

The instability in the production of rice, maize, sugarcane, cotton and oilseeds has first increased in the second period and then it declined in the third period. The instability in the production of wheat and pulses has kept on increasing with time. For cotton and fruits, the instability has declined in the second period but again increased in the third period. As a whole, the instability in the production of all the crops has kept on increasing throughout the period.

Table 9: Instability in the productivity of the crops

Crops	1990-91 to 1999-2000	2000-01 to 2009-10	2009-10 to 2016-17
Rice	0.056	0.366	0.038
Wheat	0.108	0.062	0.245
Maize	0.363	0.738	0.045
Sugarcane	0.069	0.139	0.086
Pulses	0.328	0.303	0.447
Cotton	0.541	1.158	0.493
Oilseeds	0.276	1.875	0.477
Fruits	0.987	0.273	0.089
CV	90.84	101.22	84.57

***Source*:** Author's calculation

The instability in the productivity for rice, maize, sugarcane, cotton and oilseeds has increased in the second period and then declined in the third period. For wheat and pulses, the instability has first declined and then increased in the third period. The instability in fruits however has kept on declining throughout the period. Overall, the instability in productivity of all the crops have first increased and then declined in the third period.

7. Conclusion

This study has analysed the growth pattern of the principal crops and the instability, both measured by Cuddy Della Valle index and Coppock's instability index. There were several fluctuations in the growth pattern of area, production and productivity of the crops. While the growth rate of area showed a continuous decline for wheat, it increased throughout the period for pulses. In the third period, negative growth rates were observed for the area under cotton, oilseeds and fruits. The growth rate of production also showed various fluctuations for different crops. While the growth rate of rice and wheat has declined in the second period, it increased for crops such as cotton, oilseeds and fruits. The growth rate of productivity of cotton and oilseeds have increased in the second period while it declined for rice, wheat, maize, sugarcane, pulses and fruits.

The instability in area under rice, sugarcane, pulses, cotton and oilseeds have increased in second sub-period according to Cuddy Della Valle index while it increased only for rice, wheat and cotton as measured by Coppock's instability index. Taking the entire crops, both the index found that the instability in area has first declined and then it increased in the third period and instability in production has increased throughout the period. As regard the instability in productivity, both the index has shown same result. The instability in productivity has increased for rice, maize, sugarcane, cotton and oilseeds in the second period and then declined in the third period. For wheat and pulses, the instability has first declined and then increased and for fruits, it has kept on declining throughout the period.

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