Structural breaks and Growth and Instability in Onion cultivation: The case of Saurashtra Region of Gujarat

Abstract

Onion is one of the most important commercial vegetable crops grown in India. Among the bulb crops onion is the only member grown to a great extent in this country. The historical data on area, production and yield of onion from Gujarat were collected for 26 years from the year 1992-93 to 2017-2018 and analysis was carried out using compound growth rate, Cuddy- Della Vella index and Structural break analysis (Chow test).

This study was conducted on onion cultivation in Gujarat for the study period of 1992-93 to 2017-18. To capture the impact of NHM (National Horticulture Mission), the study period was re-categorized into: Pre- NHM Period (1992-93 to 2004-05); Post- NHM Period (2005-06 to 2017-18) and Overall Period (1992-93 to 2017-18). Major onion producing districts of Gujarat were selected for analysis.

In case of growth rate and instability the yield was showed negative during study period so, more emphasis should be given to enhance the yield level with the help of innovations and technology in onion cultivation. structural break points plays a vital role regarding the forecasting purpose. For, structural break chow test was carried out, the results revealed that occur of structural break in particular district due to area and yield components used in this study.

Key words: Onion, Structural breaks, Growth rate, Instability.

1. INTRODUCTION

Onion (*Allium cepa* L) is an important spice and vegetable crop known not only for household consumption but also as the highest foreign exchange earner among fruits and vegetables. Onion has the primary center of origin in Central Asia and secondary center of origin in the Near East Asia.). It contains vitamin 'B', traces of vitamin 'C', carbohydrates,

protein and traces of minerals like iron, calcium and phosphorus. The outstanding characteristic of onion is its pungency, this is due to a volatile oil known as allyl prophyl disulphide.

It is an important bulb crop grown throughout the world and is commercially cultivated in 175 countries. It is cultivated year-round by small and marginal farmers but maximum during *rabi* season in India. India ranks second in the world in area and production of onion and third in exports after Netherlands and Spain (APEDA, 2018). Vegetable crops like onion play a unique role in developing countries like India both in economic and social sphere for improving income and nutritional status particularly of rural masses (Nagaraj, 1997).

2. Materials and methodos

This present study is based on the secondary data on area, production and productivity of onion crop during 1994-95 to 2017-18. As National Horticulture Mission (NHM) was implemented in India from 2005-06 onwards. The study period was also be classified as pre-NHM (1994-95 to 2004-05), post-NHM (2004-05 to 2017-18) and the overall period (1994-95 to 2017-18). Accordingly, for onion crop the districts of **Bhavnagar** and **Junagadh** was selected.

2.1 Structural Break Analysis:

In order to test for a structural break, we often use the Chow test (Chow, 1960) which in effect uses an F-test to determine whether a single regression is more efficient than two separate regressions involving splitting the data into two sub- samples. In Chow Test, we assume that a break point data is divided into two periods, for e.g. pre NHM period I (1994-95 to 2004-05) and post NHM period II (2004-05 to 2017-18).Separate regressions can be considered for two periods and pooling the observations for two periods together a combined regression (1994-95 to 2017-18) can also be considered.

Let us consider the two variables regression model as follows:

For Period I:

$$Y_t = \beta_{10} + \beta_{11}X_t + u_{1t} \qquad t = 1,2,...,n_1 \qquad \textbf{(1)}$$

For Period II:

$$Y_t = \beta_{20} + \beta_{21}X_t + u_{2t} \qquad t = 1, 2, \ldots, n_2 \tag{2}$$

Where, n_1 and n_2 are the number of observations in two periods. Now combining n_1 and n_2 observations, it can be consider one regression for pooled sample.

For combined period:

$$Y_t = \beta_0 + \beta_1 X_t + u_t \qquad t = 1, 2, \ldots, n_1 + n_2 \tag{3}$$

Here in each regression the error term satisfies all the classical linear regression assumptions; that is, $u_{1t} \sim NID(0, \sigma^2)$, $u_{2t} \sim NID(0, \sigma_{22})$ and $u_t \sim NID(0, \sigma^2)$ One of the main restrictions is that the variable must be equal. In other words, this regression assumes that the intercept as well as the slope coefficient remains the same over the entire period; that is, there is no structural change. If this is in fact the situation, then $\beta_0 = \beta_{10} = \beta_{20}$ and $\beta_1 = \beta_{11} = \beta_{21}$. Regression assume that the regressions in the two time periods are different; that is, the intercept and the slope coefficient are different (Gujarati, 2005).

The structural model to be used in the study of production function type and it is given as follows:

$$Q_t = \alpha_0 \ A_t^{\beta_1} \ R_t^{\beta_2} \ F_t^{\beta_3} \ Y_t^{\beta_4} \ T_t^{\beta_5} \ u_t \qquad t = 1, 2, \ldots n \tag{4}$$

Where Q_t is the aggregated production at t^{th} year, A_t is cultivated area of land at t^{th} year, R_t is the rainfall of total aggregate crop t^{th} year, F_t is aggregated fertilizer at t^{th} year, Y_t is yield for total aggregated crops at t^{th} year, T_t is the time period as a proxy for technology and u_t is the disturbance term. Here, production is dependent variable then Rainfall, area, aggregate fertilizer, yield and time period was independent variables.

Since equation no (4) it is a non-linear function, to apply OLS it will transform into log linear function as follows:

$$\ln Q_t = \ln \alpha_0 + \beta_1 \ln A_t + \beta_2 \ln R_t + \beta_3 \ln F_t + \beta_4 \ln Y_t + \beta_5 \ln T_t + u_t \tag{5}$$

$$Q_t = \beta_0 + \beta_1 A_t + \beta_2 R_t + \beta_3 F_t + \beta_4 Y_t + \beta_5 T_t + u_t \tag{6}$$

Suppose the structural change of the Cobb-Douglas production function is as:

$$Q_t = \alpha_{10} A_t{}^{\beta_{11}} R_t{}^{\beta_{12}} F_t{}^{\beta_{13}} Y_t{}^{\beta_{14}} T_t{}^{\beta_{15}} u_{1t} \quad t = 1,2,\ldots n_1 \tag{7}$$

This can be expressed in logarithmic form as:

$$Q_t = \beta_{10} + \beta_{11}A_{1t} + \beta_{12}R_{2t} + \beta_{13}F_{3t} + \beta_{14}Y_{4t} + \beta_{15}T_{5t} + u_{1t} \tag{8}$$

And after the structural change, it is

$$Q_t = \alpha_{20} A_t{}^{\beta_{21}} R_t{}^{\beta_{22}} F_t{}^{\beta_{23}} Y_t{}^{\beta_{24}} T_t{}^{\beta_{25}} u_{2t} \quad t = 1,2,\ldots n_2 \tag{9}$$

This can be expressed in logarithmic form as:

$$Q_t = \beta_{20} + \beta_{21}A_t + \beta_{22}R_t + \beta_{23}F_t + \beta_{24}Y_t + \beta_{25}T_t + u_{2t} \tag{10}$$

The test statistic of Chow-test is given below:

$$F = \frac{RSS/RSS1 + RSS2}{RSS1 + RSS2 \div (n1 + n2 - 2k)} \sim F(n_1 + n_2 - 2k) \tag{11}$$

Where, k is the number of parameters in the model including the intercept term;

RSS, RSS1 & RSS2 is the residual sum of square with (n-p), (n_1-p) & (n_2-p), respectively.

RSS= $RSS_1 + RSS_2$. Here, number of parameter k=6 then n_1=12 and n_2=12.

2.2 Compound growth rate

The compound growth rates (CGRs) of onion was calculated by using the exponential function of the following specification:

$$Y_t = ab^t$$

Where, Y_t is Dependent variable (Area, Production and productivity of onion crop in the year 't'

The parameters were estimated by converting the equation in logarithmic form and then tested for its significance by using student't' test.

2.3 Instability analysis

In order to study variability in onion, an index of instability index was used as a measure of variability. The coefficient of variation (CV) was calculated by using the following formula:
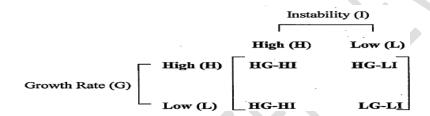
$$CV(\%) = S/\overline{X} *100$$

The trend coefficient was tested for its significance. Whenever, the trend coefficient was found to be significant, the variation around the trend rather than variation around mean was used as an index of instability. The formula suggested by Cuddy and Della (1978) was used to compute the degree of variation around the trend.

$$Ix = CV\sqrt{(1 - R^2)}$$

Where, Ix is Instability Index, CV is Coefficient of variation and R^2 is adjusted coefficient of multiple determination.

Matrix of association between Growth and Instability

Based on variation in rates and instability indices the variable under consideration were classified four fold-typology as follows

1. **High Growth/ High Instability (HG-HI):** The variables whose growth rate and instability are greater than the average;

2. **High Growth/Low Instability (HG-LI)**: The variables whose growth rate is higher than the average but the instability is lower;

3. **Low Growth/ High Instability (LG-HI)**: The variables with growth rate below average and instability above average; and

4. **Low Growth/Low Instability (LG-LI)**: The variables with growth rates and instability below average.

3. Results and discussion

3.1 Structural Break Analysis:

A Chow test is a particular test for structural change; an econometric test to determine whether the coefficients in a regression model are the same in separate sub samples. In econometrics, the Chow test is most commonly used in time series analysis to

test for the presence of a structural break. An informal test, time plot technique was used to identify the breaks in onion production of time series data during 1994-95 to 2017-18. In Chow test approach, run three regressions, for whole sample (1994-95 to 2017-2018) and for two sub samples (*i.e*, 1994-95 to 2005-06 and 2006-07 to 2017-18) by which we can compare the results before and after structural break with combine results.

Table 1: Estimation results of onion for whole period in Junagadh (1994-95 to 2017-18)

	Coefficients	Standard Error	t Stat	P-value	R^2	Chow f	Table f
Intercept (β_0)	-819.78	258.2901	-3.17	0.0052			Table f 5% 2.99612
At (β_1)	29.24	0.7971	36.68	2.27E-06	0.98	0.8000	Table f 1% 4.820574
RF (β_2)	-0.13	0.0811	-1.62	0.1222			
Ft (NPK) (β_3)	1.04	1.0675	0.98	0.3397			
Yt (β_4)	0.02	0.0068	3.96	0.0009			
T (β_5)	-1.80	4.1406	-0.43	0.6683			

From the above table 1, whole period 1994-95 to 2017-18, it was observed that β_0 = -819.78 represents if the effect of cultivated area (A_t), Rainfall (RF), Fertilizer and yield (Y_t) are zero then the average production of onion -819.78 units and t- statistic=-3.17 and p-value= 0.0052 implies that at 5% level of significance the state of technology was significant. Elasticity of cultivated area to production β_1 = 29.24 represents the production of output increases 29.24 unit if cultivated area (A_t) increases one unit, having all other coefficients are fixed and t-statistic = 36.68 and its p value= 2.27 implies that at 5% level of significance the effect of cultivated area was insignificant. Elasticity of yield to production β_4=0.02 represents the production of output increases 0.022 unit if distribution of yield

increases one unit, having all other coefficients are fixed and t-statistic = 3.96 and its p value= 0.0009 implies that at 5% level of significance the effect of distributed yield was significant. The R^2 = 0.9892 shows explanatory power of the model. Then the calculated chow statistic f value was 0.8000 less than the table f value so insignificant results was found so, there was no structural break was found in Junagadh district.

Table 2: Estimation results of onion production in Bhavnagar (1994-95 to 2017-18)

	Coefficients	Standard Error	t Stat	P-value	R^2	Chow f	Table f
Intercept (β0)	-3866.92	1121.938	-3.4466	0.0028	0.9874	6.8687	Table f 5% 2.99612
At (β1)	27.41	1.4924	18.3687	4.16E-13			
RF (β2)	-0.33	1.0320	-0.3234	0.7501			
Ft (NPK) (β3)	-1.04	5.4021	-0.1925	0.8494			Table f 1% 4.820574
Yt(β4)	0.16	0.0524	3.2241	0.0047			
t(β5)	-16.53	29.397	-0.5623	0.5808			

From the above table 2, whole period 1994-95 to 2017-18, the value of chow statistic 6.86 reveals the at least one structural break in Bhavnagar district at 5 % level of significance during the period of 1994-95 to 2017-18. In addition R^2 value of 0.98 indicates that the variable (Area, Rainfall, Fertilizer, Yield and Time period) are best fit to explain the model and 98% change in production is explained by the variable explained in the model. Among the factor considered area (27.41) and yield (0.16) show significant effect, on an average, over production at 1% and 5% level of significance respectively. Accordingly the presence of structural change in onion may be due to area and yield.

3.2 Trend in growth dimension of onion:

Onion in Gujarat has undergone significant change over the years. The production of onion has increased apparently owing to the growing importance of the crop on both the domestic and international fronts. But it has to be seen whether the production has increased due to area expansion or due to improvement in yield.

In this study, it can be seen that growth dimension of onion (i.e. area, production and yield) in different districts. The present analysis was carried out to understand the trend in area, production and yield of onion. The mean and standard deviation (S.D) of area, production and yield of major onion producing districts of Gujarat was given in Table 3. The finding show that the mean of area, production and yield in period II (2005-06 to 2017-18) in all the district was found higher when compared to period I (1994-95 to 2004-05). It validates that after implementation of NHM the mean of area, production and yield showed increasing trends in all the selected districts. In terms of overall period (1994-95 to 2017-18), Bhavnagar district recorded highest mean of area 235.69 ha, Junagadh district observed highest mean of production and yield 1221.32 tonnes and 29.80 tonnes per hectare respectively. Coming to period I, the mean of area and production was highest in Bhavnagar district 154.56 ha and 3813.31 tonnes respectively, whereas Mean of yield was highest in Junagadh district 29.77 tonnes per hectare.

Table 3: District wise mean and standard deviation of onion cultivation in Gujarat

Districts	Period I (1994-95 to 2004-05)		Period II (2005-06 to 2017-18)		Period III (1994-95 to 2017-18)	
	Mean	SD	Mean	SD	Mean	SD
Bhavnagar						
Area	154.46	78.01	316.92	122.35	235.69	130.26
Production	3813.31	2229.5	8896.12	3616.83	6354.71	3922.01
Yield	23.59	3.31	28.11	2.18	25.85	3.58
Junagadh						
Area	26.07	19.54	54.60	34.72	40.34	31.20

Production	826	717.46	1616.64	1060.24	1221.32	974.26
Yield	29.77	5.46	29.83	1.43	29.80	3.91

At the same time period II (2005-06 to 2017-18), the mean of area and production was highest in Bhavnagar 316.92 ha and 8896.12 tonnes followed by Junagadh 54.60 ha and 1616.64 tonnes respectively. The mean of yield was observed highest in Junagadh 29.83 tonnes per hectare.

The results from the analysis revealed that the Bhavnagar (2.08% per annum) showed positive non-significant growth whereas Junagadh (-1.69% per annum) recorded negative and non-significant growths in area during period I. simultaneously, the compound growth rate of production was found positive and non-significant in Bhavnagar (3.14% per annum) while Junagadh (-0.85% per annum) showed negative non-significant growth rates. The productivity growth rate of Bhavnagar (1.00% per annum) and Junagadh (0.74% per annum) showed positive and significant growth during Period-I.

Table 4: District wise compound growth rate analysis of onion in Gujarat

Study Period						
Districts	Period I (1992-93 to 2004-05)		Period II (2005-06 to 2017-18)		Period III (1992-93 to 2017-18)	
	CGR(%)	SE(b)	CGR(%)	SE(b)	CGR(%)	SE(b)
Bhavnagar						
Area	2.08	0.70	0.58	0.58	4.91	0.63
Production	3.14	0.82	0.66	0.60	6.06	0.72
Yield	1.00***	0.14	0.08***	0.07	1.19***	0.11
Junagadh						
Area	-1.69	0.78	-9.39	0.78	3.39	0.99
Production	-0.85	0.82	-9.45	0.73	3.55	0.78
Yield	0.74***	0.17	-0.10***	0.04	0.17***	0.13

For period II (2005-06 to 2017-18)**,** the district wise growth rate of area showed positive and non-significant growth in Bhavnagar (0.58% per annum) whereas Junagadh (-9.39 % per annum) showed negative and non-significant growth. The production growth rate revealed same trend like area, showed positive and non-significant growth in Bhavnagar (0.66% per annum) whereas Junagadh (-9.45 % per annum) showed negative and non-significant growth. The growth of productivity was found to be positively significant for Bhavnagar (0.08% per annum) and negative but significant in Junagadh (- 0.10% per annum)

Coming to the overall study Period III (1992-93 to 2017-18), the growth rate of area showed positive and non-significant growth in all the selected districts and Bhavnagar (4.91% per annum) district had highest growth rate followed by Junagadh (3.39% per annum). The growth rate of production were also found positive and significant growth rate in both the district under study. The productivity growth rate was observed positive and significant at 1% level in Bhavnagar (1.19 % per annum) and Junagadh (0.17 % per annum) districts. The influence of NHM was positive in growth rate of area, production and yield. Bairwa *et.al.,* analysed the growth performance of fruit crops, they also found positive growth rate in area, production and yield over the study period (1991 to 2007). The area under sapota was registered highest CGR of 11.74 per cent followed by citrus (4.98 per cent), mango (4.58 per cent) respectively.

3.3 Instability analysis of onion in Saurashtra region:

Instability means deviation from the trend. Coefficient of variation and Cuddy- Della Valle Index (corrected coefficient of Variation) were used in the present study to calculate instability in onion cultivation. The index of CDV is preferred over CV because it can provide clear direction about instability in the variable and to examine the extent of risk involved in

onion production. Besides CV has some limitations in calculating instability of time series data, as it discards trend and thereby overestimate instability. That is why, CDV alone should be used when there is significant trend. Otherwise CV (%) alone sufficient to measure instability. Significance of the trend is determined by running a simple OLS regression whereby t statistic obtained to test the effect of beta coefficients. The effect of beta coefficient significant would trends indicate the significance of the underlying trend. A high value of this index indicates the high instability in production and vice-versa.

The results of instability analysis of onion crop in selected two districts are presented in Table 4. From the analysed results, it was observed that in period I (1992-93 to 2004-05), as CDV (%) was found insignificant for area in Junagadh districts and the production was insignificant in Bhavnagar and Junagadh districts so, CV (%) considered to measure of instability. The instability measures CDV (%) of area was highest in Bhavnagar (49.98%). At the same time for yield, lowest instability was found in Bhavnagar district (13.90 %). In terms of CV (%) the instability of area was found highest in Junagadh (85.19 %) district.

In period II (2005-06 to 2017-18), the instability in area was found to be highest in Junagadh district with the CDV value of (66.85 %) district. In case of production, a similar trend was found in instability. Junagadh district recorded highest instability with the CDV value of (69.01 %).

Table 5: District wise instability analysis during (1992-2018):

Study Period						
Districts	Period I (1992-93 to 2004-05)		Period II (2005-06 to 2017-18)		Period III (1992-93 to 2017-18)	
	CV (%)	CDV(%)	CV (%)	CDV(%)	CV (%)	CDV(%)
Bhavnagar						
Area	50.50	49.98	45.71	43.68	57.51	46.42
Production	58.46	55.61^	47.32	45.13	63.50	50.15^
Yield	14.05	13.90	27.74	26.46	23.57	18.65

Junagadh						
Area	85.19	83.16^	72.61	66.85	78.01	77.53
Production	87.69	86.66^	75.13	69.01	81.05	79.62
Yield	28.04	28.74	31.24	31.13	24.00	20.71

Note: 1. CV-Coefficient of variation (%), CDV-Cuddy-Della Vella index (%).

2. ^- Non significant values and only CV (%) is to be considered.

During the overall period (1992-93 to 2017-18), CDV (%) of production variable in Bhavnagar district found insignificant that is why CV (%) taken for measure of instability. The area was ascertained with highest instability in Junagadh (77.53 %) district. Similar result was also found in production also Junagadh district (79.62 %) was observed highest instability. In case of productivity Junagadh (20.71%) and Bhavnagar (18.65 %) observed medium instability. The results showed that after the implementation of NHM the instability rate decreased compared to pre-NHM period. Deka, S. (2018) analysed the instability of vegetable crops in north eastern states, the result revealed that instability of yield variable was less compared to area and production instability as same as in this study and Nagaland state gives highest instability with CDV (%) of area (68.4 %) and production (34.1 %).

3.4 Trade of between growth and instability

Matrix of association between growth and instability figures (%) was carried out using the four fold typology as given in methodology section. The four fold typology consisted of the following desirable and non-desirable situation:

High Growth-Low Instability: Most desirable situation

High Growth-High Instability: Desirable situation

Low Growth-Low Instability: Least desirable

Low Growth-High Instability: Not desirable

Accordingly, the classification of growth and instability in terms of area, production and yield of the onion was in turn assumed in the following order as per the existing literature available (Das, K. 2016):

Low growth	: < 10%	Low instability	: < 30%
High growth	: > 10%	High instability	: > 30%

Table 6: Growth-instability trade-off in area, production and productivity of onion in Gujarat during 1992-93 to 2017-18:

Area particular	High growth	Low growth
High instability		Bhavnagar (4.9, *46.42*) Junagadh (3.39, *77.53*)
Low instability		
Production particulars	**High growth**	**Low growth**
High instability		Bhavnagar (6.06, *63.50*) Junagadh (3.55, *79.62*)
Low instability		
Productivity particulars	**High growth**	**Low growth**
High instability		
Low instability		Bhavnagar (1.19, *18.65*) Junagadh (0.17, *20.71*)

Note: Value in bold and italics indicate growth (%) and instability (%), respectively.

High Growth-Low Instability (Most desirable situation): In this most desirable situation not even one study district was positioned neither yield nor other factors.

High Growth-High Instability (Desirable situation): None of the district fall in this category in terms of area, production and productivity.

Low Growth-Low Instability (Least desirable): In terms of area and production none of the district fall under this category, But in case of yield Bhavnagar and Junagadh both districts comes under this category Thereby, it may be suggested that to increase the growth rate of

onion production in these district there is need to popularize the high yielding varieties of onion to farmers.

Low Growth-High Instability (Not desirable): In terms of area and production Bhavnagar, and Junagadh both districts fall under this category, need to be introspected not only the scientific community but also by the policy makers. Assured incentives may be given to the farmers for faster adoption of technologies and technical practices.

4. Conclusion

In terms of growth rate and instability the yield was showed negative during study period so, more emphasis should be given to enhance the yield level with the help of innovations and technology in onion cultivation. As the growth- instability trade-off has placed most of the districts either 'not desirable' or 'least desirable' category with respect to area, production and yield components so, it is suggested that the institutional intervention should be put in place to maintain area, production and yield. The findings of structural break points plays a vital role regarding the forecasting purpose. Without finding structural break points, someone can make a misleading conclusion regarding forecasting or prediction. To maintain the stable condition in onion production the research and research finding will helpful.

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