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GROWTH AND STRUCTURAL STABILITY OF WHEAT PRODUCTION: A STUDY WITH SELECTED COUNTRIES

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Abstract: This study aims to estimate growth and structural stability of annual wheat production in ten major producing countries in the world following Semi-logarithmic growth model for the period 1961 to 2018 using FAO(Food & Agricultural Organization) dataset. The results show that for the majority of the countries seven out of ten, annual wheat production is found to be stationary except China, France and USA while wheat production show nonstationarity for the latter three countries The long term estimated growth rates are found to be over 3% for China, India and Pakistan during this period. The structural stability of the models have been tested for each country wheat production following Bai-Perron multiple breakpoint tests and found that except Australia, Russia and Ukraine, all the countries exhibit single/multiple breakpoints. These observations are associated with routine challenges such as competition for land and climate concerns.

Keywords: structural stability; wheat production; semi-logarithmic growth model; climate concerns

JEL Classification: C22, Q10, Q18

1. INTRODUCTION

The economic importance of wheat (*Triticumaestivum L.)* and its contribution to the diets of humans and livestock cannot be disputedWheat is the most important staple crop in temperate zones and is in increasing demand in countries undergoing urbanization and industrialization .(Shewry and Hey (2015)). In addition to being a major source of starch and energy, wheat also provides substantial amounts of a number of components which are essential or beneficial for health, notably protein, vitamins (notably B vitamins), dietary fiber, and phytochemicals.It may be noted that wheat has good nutrition profile with 12.1 per cent protein, 1.8 per cent lipids, 1.8 per cent ash, 2.0 per cent educing sugar, 6.7 per cent pentose, 59.2 per cent

starch good source of mineral of vitamin and nicotinic acid(Agam *et al.* (2017)). In terms of global production wheat is the third most important crop in the world after maize and rice with total world wheat production being stood at 735 million tonnes in 2018 (*www.faostat.com*). Unlike rice and maize, wheat is cultivated from Scandinavia and Russia to Argentina, including elevated regions in the tropics and subtropics (Feldman (1995)). Wheat was one of the first domesticated food crops and for 8 000 years has been the basic staple food of the major civilizations of Europe, West Asia and North Africa (*http://www.fao.org/3/y4011e04.htm*). Furthermore, there is an increasing demand for wheat in new markets beyond its region of climatic adaptation.

The changing structure of agriculture in OECD countries has been linked to technology, economy and world-wide market forces, and to governmental policies (Huffmen and Evenson(2001)).There is emerging evidence of a pervasive structural change in the rate of crop (and wheat) productivity growth worldwide (Pardey (2011), Alston (2010c)). The growth of global wheat production has exhibited slowdown in recent years in particular, since 1990. This productivity slowdown was preceded by a reduction in the rate of growth in agricultural R&D spending in many countries throughout the world and a shift away from farm-productivity-oriented R&D in at least some of the largest research systems in the world. Another equally important phenomenon that has taken place in agriculture from the global perspective is the shifting location of agricultural production (Alston (2010a, 2010b)). Apart from agroecological factors such as climate, soils, land slope and elevation, wind and day-length, technology, population densities, investments in rural infrastructure, cold chain play significant role in determining the optimal location of production.

But stable growth of major staple diet such as wheat are essential to meet growing demand due to increasing population, income as well as changing food pattern across the globe.Moreover, for sustaining growth understanding growth and stability in wheat production in major producing countries are very relevant.The ten countries have been selected to represent major wheat producing areas in the world. These countries are Australia, Canada, China, France, Germany, India, Pakistan, USA, Russian Federation and Ukraine. These top ten wheat producing countries on averagecontribute around 70% of the global wheat production. Taking China and India together produce around one third of the global wheat production. However, France and Germany are having highest yield (hectagram/hectre) at 68427 and 66737 respectively, in the year 2018.

China alone has produced more than 131 million tonnes of wheat in the year 2018. The country has 24 million hectares dedicated to growing wheat, which is an area roughly the same size as Algeria.

Indian Green Revolution led to a massive increase in wheat production, with a doubling of national wheat production seen within the single decade between

1960 and 1970. Uttar Pradesh, Punjab, Haryana, and to some extent Madhya Pradesh have got the benefit of this technological revolution in agriculture.

At the global level, wheat production has been facing a lot challenges both routine (institutional/technological) as well as climate change (environmental) which are causing a lot of threats to the growth and stability of production across the traditional belt of wheat production. Changes in climate can influence food production in a variety of ways, as the climates of major production areas may change with respect to growing season length, as well as changes in average temperatures and rainfall (Enghiad *et al.* (2017)).

This study intends to explore growth and structural stability of wheat production in the top ten wheat producing countries in the world during the period 1961 to 2018 following multiple structural break analysis due to Bai and Perron(1997, 1998, 2001, 2003) and show that how these countries wheat output fluctuate in terms of growth during different phases in the last sixty years.

This paper has been organized as follows. The next section deals with data and methodology. Empirical results are discussed in Section 3. Summary and conclusions are presented in Section 4.

2. DATA AND METHODOLOGY

The data on annual wheat production of top ten[2] wheat producing countries are collected from the Food and agricultural Organization. (*www.fao.org*) covering the period 1961 to 2018. The econometric methodology used in the analysis are exploratory using tables, charts, diagramin nature. Apart from summary statistics,the stationarity test called Augmented Dickey Fuller(ADF) test has been applied to check the stationarity status of wheat production at level of the ten countries considered are carried out. We then consider the following semilogarithmic equation for each ten separately to estimate long term growth of wheat production of that country for the period 1961 to 2018. These estimates enable us to understand variation in estimated growth rates across these nations.

$$\ln y_{it} = \alpha + \beta t + u_t, \text{ t=1,2,….,58.} \quad (1)$$

α ::Intercept

β : Growth coefficient

u_t Error term

y_{1t} **:** Annual wheat production of Australia in th year

y_{2t} **:** Annual wheat production of Canada in th year

y_{3t} **:** Annual wheat production of China in th year

y_{4t} : Annual wheat production of France in th year

y_{5t} : Annual wheat production of Germany in th year

y_{6t} : Annual wheat production of India lia in th year

y_{7t} : Annual wheat production of Pakistan in th year

y_{8t} : Annual wheat production of Russian Federation in th year

y_{9t} : Annual wheat production of Ukraine in th year

y_{10t} : Annual wheat production of USAinth year

Once estimation is done, we carry out a stability analysis of the growth coefficient during this period for each country by following Bai Perron multiple structural break tests corresponding to equation(1)..

We have tested for the presence of structural stabilityof growth coefficient in each of wheat production series corresponding to ten countries. The literature on parameter stability test of an econometricmodel beginning with the classic work by Chow (1960) is vast and comprehensive. However, the Chow test has some limitations. Andrews (1993) proposed a proper statistical test for a stationary series with an unknown single structural breakpoint. As regards testing for the presence of multiple structural breaks and that too in case of nonstationary series as well, the first major breakthrough was given by Bai and Perron (1998, 2001).

In a subsequent paper in 2003, they advocated, based on extensive simulations, that under very general conditions on the nature of data and the error term, the following testing procedure involving basically two test statistics viz., the UD max test (and/or the WD max test), and the sup F type test i.e., a sequential test of the null hypothesis of l breaks versus the alternative of (l + 1) breaks, be followed. First, the UD max and/or WD max tests are used to see if at least one break is present. If these indicate the presence of at least one break, then the number of breaks can be decided based upon a sequential examination of the sup statistics. It may be noted that in the later the test F (1| 0) is ignored.

As already stated, we have applied the Bai-Perron multiple breaks point tests to find parameter stability in all the whaet production series for all the ten countries. Once the break years are determined, we have estimated the equations with rice production at level(logarithm) as the dependent variable and intercept and/or linear trend as an explanatory variable for each country in each subperiod determined endogenously. This exercise enables us to understand the impact of structural change in terms of growth for each series involved.

3. EMPIRICAL RESULTS

In this section, the empirical results applying the stated methodology are discussed. The diagram (see figure I) depicted below shows that USA remained the leading wheat producer in the world till 1983, however,since then China has been consistently maintaining the first position followed by India. We have presented cropped area, crop yield(production per unit of cropped area) and total production of wheat for these top ten producing countries for the year 2018 in table 1 below. The table shows that India has the largest cropped area for the wheat crop followed by Russia and China. However, in terms of yield crop for wheat France and Germany are in first two positions with 6842.7 kg per unit hectare and 6673.7 kg per unit hectare, respectively. It may also be observed from this table that in six countries among the top ten producers of wheat yield crop is lower than the world average. Apart from France and Germany, only China and Ukraine are having higher crop yield for wheat compared to the world average.

The unit root test results for all the ten series of wheat production are presented in table 2 below. The ADF test statistics at level values as well as at first difference (wherever applicable) have been carried out considering proper assumption on deterministic components such as constant and/or trend. Except China, France and USA, all the series of wheat production are found to be stationary at level values. The wheat production series for China, France and France are found to stationary at first difference. It may be observed from the table 2 that ADF test statistic value corresponding to wheat production series of Australia is found to be -7.260 which is highly significant at 1% level implying the stationary series. The ADF test statistic values corresponding to wheat production series at level values for Canada, Germany, India, Pakistan, Russian Federation and Ukraine are -5.107, -3.874, -4.760, -7.687, -3.387 and -4.510, respectively which are all significant at appropriate level(s) confirming stationarity status for all these series.

Once the stationarity status are confirmed, we estimate long run growth of the wheat production series following semilogarithmic model as shown in equation (1) in the previous section. The estimation has been conducted by ordinary least squares (OLS) method. The regression results are presented in table 3 below. The long-run estimated growth rates as presented in table 3 demonstrate that India achieved 3.882% growth rate which is highest followed by China at 3.388%. Another country that experienced over 3% longterm growth in wheat production is Pakistan. The countries those achieved over 2% but below 3% growth rate are France, Germany and the Russian Federation. Australia, Canada and Ukraine experienced between 1-2% growth rate. However, wheat production grows in the USA merely at 0.008% during this period requires some special attention.

As most of the series span a reasonably long period of time over 58 years which may contain presence of major changes in policy environment or changes

in technology/institutions. In this context, we carry out stability analysis to understand whether there has been significant changes in growth parameter corresponding to each wheat production series of the top ten producing countries. By applying the UDmax and WDmax tests, it is found that the null hypothesis of 'no break' is rejected in favour of 'one break' for seven out of ten series at level values as presented in Table 4. Thereafter the sequential sup F-type test with trimming parameter value 0.15 was carried out, and the estimated numbers of break dates in those series were obtained along with the estimated break dates. The multiple structural break results show that the null hypothesis of 'no break' could not be rejected for the wheat production series for three countries namely Australia, Russian Federation and Ukraine.

This suggests that wheat production levels in seven major countries including China and India have exhibited structural change during this period. for these countries which suggests that the breaks or instability in the time series of wheat production due to institutional and/or technological change have caused break in trend.The results presented in table 4 demonstrate that three countries namely China, Germany and India experienced structural change twice in their wheat production series whereas rest of the countries experienced single break. It is also noteworthy that most of the countries experienced at least one structural break in 1980's implying the role of major policy changes in terms of technology/institutions during this period.

The structural stability analysis in detail are presented in tables from 5A through 5G. As already discussed above, we have not found any structural change in wheat production for Australia during 1961 to 2018. It is observed from table 5A that Canada experienced a single structural change in the year 2001, as a result which long run growth of wheat production has been found to be 2.819% in the post break period compared to the pre break period of 1.963%. It may further be noted that as a result of considering the statistical issue of parameter stability the model has improved with adjusted R^2 of 0.56 compared to 0.463 when entire period was considered.

We now discuss the parameter stability issue with reference to wheat production of China as presented in table 5B. As already stated that China experienced two structural break in wheat production in the years 1983 and 2000. It may further noted that wheat production in China grew at a very high rate of 6.70% during the period 1961-1982. This may be related to the institutional change ofdecollectivisation policies of the Chinese Government since 1970s under which land use rights were provided to each household reaching and staying at a level of 99 per cent of villages in 1984 (Rozelle and Huang(2000)). However, wheat production grew only at 2.192% during the period 1983 to 1999 before slightly improving to 2.391% during 2000 to 2018. This may be due to the rapid urbanization in China thus eating up millions hectares of farm land which were engaged in production of traditional crops such as wheat, rice and corn, along with environmental degradation (Li *et al* 2014).

We now found from the tables 5C and 5D that France and Germany, the two leading countries of in terms of wheat yield, that both these two countries are experiencing sluggish growth in recent times at less than 1% in wheat production.

The stability analysis of growth estimation results of wheat production for India are presented in table 5E. It is observed that India has exhibited two structural break in wheat production in the years 1969 and 1989. The first break is quite obvious as Indian agriculture in particular wheat production experienced 'green revolution' through the introduction of high yielding dwarf varieties in late 1960's through technological change in agriculture. The results show that during the period 1969 to 1989, wheat production grew at a massive high rate of 4.882% before slew down to 2.10% during the period 1989 to 2018.

Pakistan observing structural change in the 1981 in wheat production has also experienced slow growth rate in the post break period at 2.425% compared to 5.542% during the pre break period 1961 to 1980 as presented in table 5F.

The USA, another leading producer of wheat has experienced a negative growth rate in wheat production during the period 1985 to 2018 at -0.03% compared to its pre break period of 3.86%. as presented in table 5G..

4. CONCLUSIONS

This study has been conducted to understand stable growth rates of wheat production of the top ten producers for the period 1961 to 2018 using FAO data set and using a semilogarithmic growth model along with Bai-Perron multiple structural breakpoint tests. It is observed from this analysis that except Australia, Russia and Ukraine, all the leading countries experienced structural instability considering the whole period in wheat production. Furthermore, these seven countries observed single/multiple structural break in their wheat production. It is observed that majority of the traditional wheat producing countries found at least on structural break in 1980's. It has also been found that in the last three decades growth rates of wheat production have slowed down in major producing countries due to technological/institutional/ environmental change. It may be necessary to note that China and India two leading producers are experiencing low growth rates in wheat production which are facing routine challenges such as competition for land for alternative uses such as industrial or cash crop, and climate concerns.

As reported in the *New York Times* in the year 2004, the rapid urbanization has been eating up crop land in China and farmers have also stopped producing traditional crops such as rice, wheat etc. and converting their land for lucrative cash crop driven by market mechanism. Another reason for the loss of farmland is that more acreage is being converted to grazing for the fast increase in livestock. Environmental degradation is also another causing factor in the slowing down of wheat production growth in China.

India, the second largest producer of wheat has also been facing several constraints both routine challenges such as competition for cultivable land, irrigation and energy along with as well as climate change due to its vulnerability which are all causing slowing growth of wheat production as observed since late 1980's. It may be worthwhile to note in this context that a significant partof India's wheat area is under heat stress such as Gangetic Plain and Central and Peninsular India.

As wheat production is related with food security question of the major developing countries, the observed slowing down of this important food crop since late 1980's across the traditional belt should be a major policy concern for these countries.

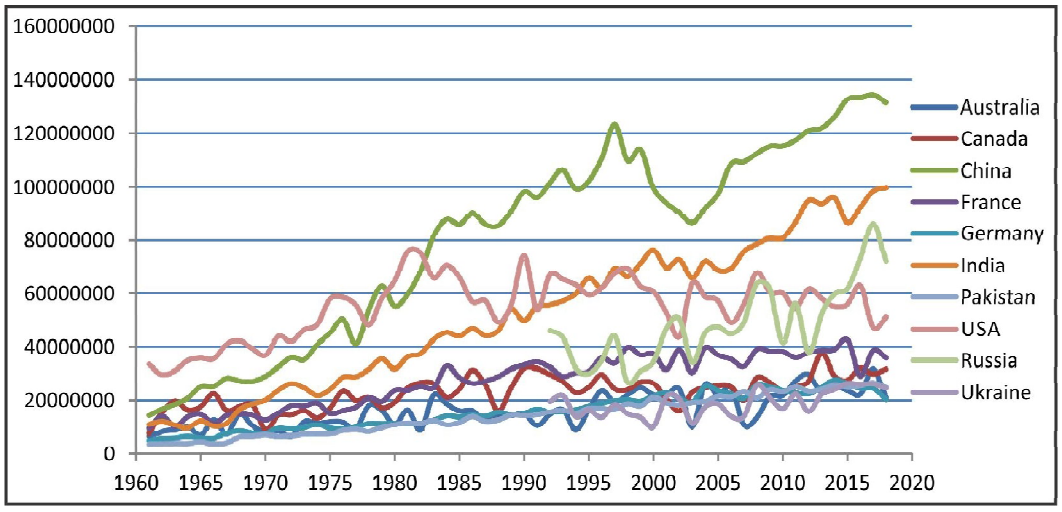

Figure I: Wheat Production(inTonnes) of Top ten countries during 1961-2018

Table 1: Summary of Wheat Production, Yield and Area Cropped in 2018 of Top ten countries

Country /Region	*Cropped Area (hectare(ha))*	*Yield (hg/ha)*	*Wheat Production (Tonnes)*
Australia	10919180	19178	20941134
Canada	9881000	32152	31769200
China	24268794	54163	131447224
France	5231615	68427	35798234
Germany	3036300	66737	20263500
India	29580000	33705	99700000
Pakistan	8797227	28505	25076149
Russian Federation	26472051	27250	72136149
Ukraine	6619600	37242	24652840
USA	16027750	31999	51286540
World(Total)	214791468	34228	735179776

Source: FAOSTAT, 2019

Table 2: Results of Unit Root Test of Wheat Production

Series: Wheat production (at level values)	*ADF test statistic value*		*p-value*		*Deterministic component*	
	Level	*First diff.*	*Level*	*First diff.*	*Level*	*First diff.*
Australia	-7.260	————-	0.000	———	constant, trend	———-
Canada	-5.107	————-	0.000	———-	constant, trend	————
China	-1.906	-7.509	0.638	0.000	constant, trend	constant
France	—2.161	-14.772	0.501	0.000	constant, trend	constant
Germany	-3.784	———	0.025	———	constant, trend	———-
India	-4.760	————-	0.001	———-	constant, trend	————
Pakistan	-7.687	———	0.000	——-	constant, trend	————-
Russian Federation	-3.787	——-	0.034	——-	constant, trend	——-
Ukraine	-4.510	————-	0.01	———-	constant, trend	———-
USA	-3.011	-10.140	0.138	0.000	constant, trend	constant

Notes: All the test statistic values are compared with MacKinnon (1996) one-sided critical values. Level values are in natural logarithm.

Source: Author's own calculation

Table 3: Estimating Growth equation of wheat production in Semilogarithmic form

$$\ln y_{it} = \alpha + \beta t + u_t$$

Country (Dependent variable)	*Variable*	*Coefficient*	*Standard error*	*t-statistic*	*p-value*	*Adj.R^2*
Australia($\ln y_{1t}$)	*Constant*	15.94291	0.071942	221.6067	0.0000	0.597
	Trend	0.019613	0.002121	9.246844	0.0000	
Canada($\ln y_{2t}$)	*Constant*	16.54219	0.059772	276.7569	0.0000	0.463
	Trend	0.012471	0.001762	7.076778	0.0000	
China($\ln y_{3t}$)	*Constant*	17.03835	0.067761	251.4482	0.0000	0.834
	Trend	0.033879	0.001998	16.95901	0.0000	
France($\ln y_{4t}$)	*Constant*	16.39299	0.046228	354.6146	0.0000	0.826
	Trend	0.022444	0.001363	16.46827	0.0000	
Germany($\ln y_{5t}$)	*Constant*	15.68273	0.031803	493.1183	0.0000	0.935
	Trend	0.026836	0.000938	28.62118	0.0000	
India($\ln y_{6t}$)	*Constant*	16.41858	0.054080	303.5986	0.0000	0.912
	Trend	0.038822	0.001594	24.34955	0.0000	

contd. table 3

Country (Dependent variable)	*Variable*	*Coefficient*	*Standard error*	*t-statistic*	*p-value*	*Adj.R^2*
Pakistan($\ln y_{7t}$)	*Constant*	15.34792	0.037261	411.9014	0.0000	0.943
	Trend	0.033644	0.001099	30.62643	0.0000	
Russian Federation	*Constant*	17.26279	0.079379	217.4718	0.0000	0.542
($\ln y_{8t}$)	*Trend*	0.027933	0.004955	5.637517	0.0000	
Ukraine($\ln y_{9t}$)	*Constant*	16.46217	0.091466	179.9820	0.0000	0.270
	Trend	0.018589	0.005709	3.255966	0.0032	
USA($\ln y_{1t}$)	*Constant*	17.56895	0.050984	344.6000	0.0000	0.305
	Trend	0.007663	0.001503	5.097972	0.0000	

Table 4: Results of the Bai-Perron Multiple Structural Breakpoints Test in level values

Country Series (Wheat production in natural logarithm)	*UD Max statistic*	*WD Max statistic*	*No. of Break*	*Break Years*
Australia	6.070480	9.306052	0	———-
Canada	14.35796*	19.18874*	1	2001
China	432.6142*	487.0850*	2	1983,2000
France	97.529308*	97.52930*	1	1984
Germany	63.33758	64.80554	2	1975,2004
India	180.6079	180.6079	2	1969, 1989
Pakistan	180.6079	139.0424	1	1981
Russian Federation	10.81822	14.84271*	0	———
Ukraine	11.10791	15.28780*	0	———
USA	140.3786	140.3786	1	1985

· Significant at 5% level.

Table 5A: Results of Stability of Structural semilogarithmic Growth model of wheat production of Canada

Dependent variable (Break period)	*Variable*	*Coefficient*	*Standard error*	*t-statistic*	*p-value*	*Adj.R^2*
$\ln y_{2t}$ (1961 – 2000)	*Constant*	16.43486	0.065529	250.8034	0.0000	0.560
	Trend	0.019631	0.002785	7.048174	0.0000	
$\ln y_{2t}$ (2001 – 2018)	*Constant*	15.67663	0.459799	34.09451	0.0000	
	Trend	0.028185	0.009238	3.050889	0.0035	

Table 5B: Results of Structural Stability of semilogarithmic Growth model of wheat production of China

Dependent variable (Break period)	*Variable*	*Coefficient*	*Standard error*	*t-statistic*	*p-value*	*Adj.R^2*
$\ln y_{3t}$ (1961 – 1982)	*Constant*	16.56642	0.028942	572.3999	0.0000	0.989
	Trend	0.067008	0.002204	30.40817	0.0000	
$\ln y_{3t}$ (1983 – 1999)	*Constant*	17.71559	0.101887	173.8756	0.0000	
	Trend	0.021922	0.003246	6.752894	0.0000	
$\ln y_{3t}$ (2000 – 2018)	*Constant*	17.35782	0.135420	128.1773	0.0000	
	Trend	0.023911	0.002747	8.705754	0.0000	

Notes: Trimming parameter value is 0.15.

Table 5C: Results of Stability ofStructural semilogarithmic Growth model of wheat production of France

Dependent variable (Break period)	*Variable*	*Coefficient*	*Standard error*	*t-statistic*	*p-value*	*Adj.R^2*
$\ln y_{4t}$ (1961 – 1983)	*Constant*	16.17333	0.045528	355.2384	0.0000	0.936
	Trend	0.035875	0.003320	10.80416	0.0000	
$\ln y_{4t}$ (1984 – 2018)	*Constant*	17.03562	0.074650	228.2052	0.0000	
	Trend	0.007708	0.001768	4.359998	0.0001	

Notes: Trimming parameter value is 0.15.

Table 5D: Results of StructuralStability of semilogarithmic Growth model of wheat production of Germany

Dependent variable (Break period)	*Variable*	*Coefficient*	*Standard error*	*t-statistic*	*p-value*	*Adj.R^2*
$\ln y_{5t}$ (1961 – 1974)	*Constant*	15.43170	0.039655	389.1524	0.0000	0.978
	Trend	0.053484	0.004657	11.48422	0.0000	
$\ln y_{5t}$ (1975– 2003)	*Constant*	15.66404	0.047057	332.8716	0.0000	
	Trend	0.029371	0.001559	18.83897	0.0000	
$\ln y_{5t}$ (2004 – 2018)	*Constant*	16.96756	0.214862	78.96954	0.0000	
	Trend	0.000500	0.004198	0.119115	0.9056	

Notes: Trimming parameter value is 0.15.

Table 5E: Results of Structural Stability of semilogarithmic Growth model of wheat production of India

Dependent variable (Break period)	*Variable*	*Coefficient*	*Standard error*	*t-statistic*	*p-value*	*Adj.R^2*
$\ln y_{6t}$ (1961 – 1968)	*Constant*	16.12702	0.063045	255.8024	0.0000	0.987
	Trend	0.031878	0.012485	2.553356	0.0136	
$\ln y_{6t}$ (1969– 1988)	*Constant*	16.36779	0.060799	269.2104	0.0000	
	Trend	0.048822	0.003138	15.56049	0.0000	
$\ln y_{6t}$ (1989– 2018)	*Constant*	17.18876	0.075696	227.0751	0.0000	
	Trend	0.021039	0.001707	12.32749	0.0000	

Notes: Trimming parameter value is 0.15.

Table 5F: Results of Stability of Structural semilogarithmic Growth model of wheat production of Pakistan

Dependent variable (Break period)	*Variable*	*Coefficient*	*Standard error*	*t-statistic*	*p-value*	*Adj.R^2*
$\ln y_{7t}$ (1961 – 1980)	*Constant*	15.07026	0.035041	430.0693	0.0000	0.983
	Trend	0.055423	0.002925	18.94663	0.0000	
$\ln y_{7t}$ (1981 – 2018)	*Constant*	15.74444	0.045746	344.1715	0.0000	
	Trend	0.024258	0.001116	21.73830	0.0000	

Notes: Trimming parameter value is 0.15.

Table 5G: Results of Stability of Structural semilogarithmic Growth model of wheat production of USA

Dependent variable (Break period)	*Variable*	*Coefficient*	*Standard error*	*t-statistic*	*p-value*	*Adj.R^2*
$\ln y_{8t}$ (1961 – 1984)	*Constant*	17.18253	0.043340	396.4604	0.0000	0.800
	Trend	0.038576	0.003033	12.71822	0.0000	
$\ln y_{8t}$ (1985 – 2018)	*Constant*	18.01979	0.076676	235.0115	0.0000	
	Trend	-0.003201	0.001798	-1.780179	0.0807	

Notes: Trimming parameter value is 0.15.

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