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STRUCTURAL BREAK IN RICE PRODUCTION : A STUDY WITH ASIAN COUNTRIES

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Abstract

As rice is the most important staple diet in Asia because of its high concentration of production and consumption in the region it is key to global food security. In this backdrop, understanding the stable growth of rice production through structural break analysis is quite important. This study attempts to investigate the presence of structural change in annual rice production for the major ten Asian rice producing countries for the period 1961 to 2016 following the Bai-Perron multiple breakpoint test and found significant changes after Asian Green revolution in level values but no break in growth. This study also found a sharp rise in intercept following intervention analysis and mixed results using linear trend analysis. Countries like China and India exhibited positive impact following structural change but the countries like Myanmar, Thailand and Vietnam experienced negative effect which might be associated with major institutional and/or technological changes of these countries involved including the rice crisis of 2008.
Key words:*Asian green revolution; intervention analysis; persistence of shocks; profound impact ; Bai-Perron multiple break point test*
JEL Codes: *C22, Q10, Q18*

1. Introduction

In many countries of South and South East Asia rice plays a significant role in the agrarian system and livelihood of the majority of cultivators. For many years rice has remained a staple food and a cultural identity for a large segment of the Asian countries. Although for the world as a whole rice is a staple food for 50% of the population this figure goes to 70% for the Asian continent. Rice is considered a necessity, a staple food, a source of livelihood for many poor (or near poor) households and an object of considerable cultural and social importance, yet it is rarely cast as a growth engine in a modern economy. In the economic realm, rice has thus been overshadowed (World Bank (2014)). This region is also called the 'Rice Bowl' which produces around 90 per cent of world's rice, with China and India together accounting for almost 50 per cent of the total production in the world (FAO 2016). However, this region has a diverse production system and consumption pattern in terms of rice as a commodity. In the last fifty years, rice production has been threefold mainly due to technological and institutional change in this region. However, demand for rice consumption is also increasing due to increase in income and population in some parts of Asia such as the Philippines, Myanmar, Cambodia, Bangladesh and Laos, and is expected to rise in Sub-Saharan Africa and Latin America in near future (IRRI Africa Rice and ICRISTAT). So in order to meet this increasing global rice demand, the discussion of growth and acceleration of rice production is very important apart from the perspective of food security and nutrition. It has been pointed out in a paper by Ghose et al. (2013) that rice is still the most potential means to improve the food security situation and resolve undernourishment. This study has also demonstrated that self-sufficiency in rice production is paramount to its domestic food security, and thereby proposes that emphasis should be given on increased rice production which is decelerating amid the upsurge of modern economic sectors. Despite the importance of rice as a basic staple, global trade accounts for only 6.5 per cent of consumption. This also indicates that most countries are self-sufficient in rice production and face increased price volatility in times of production shortfalls (World Bank).

As already discussed, rice is the backbone of this vast economy of the region considering high rural population share and rural employment absorption. The literature on rice research is vast and comprehensive. This literature of rice production, consumption and trade in Asia has mainly focused on determinants of growth of rice production (Milovanovic and Smutka(2017)). Stable growth of rice production in Asia has important implications for global food security (Bandumula(2018)). Detailed policy choices for rice in a dynamic East and South East Asia have been discussed in the World Bank policy document published in 2017. There are also some attempts to understand food security changes in Asia (Monika(2013)). Although major Asian countries are exhibiting deceleration in growth of rice production, West African countries are rising as a new hub for rice production through improvement in the supply chain(Ramziath and John(2013), USAID (2009)). Again, the growth of rice productivity research has an important impact (both direct and indirect) for the alleviation of rural poverty in Asia.(Datt and Ravallion(1998), Dawe(2000)).

However, no comprehensive study has been carried out to understand the presence of the structural break in the level and growth of production of this most important staple food. It may be pointed out in this context that major structural change in terms of technological improvement with high yielding variety seeds, use of fertilizer and pesticide along with mechanization has taken place in the whole Asian continent which has been later termed as 'Asian Green Revolution' by the researchers. The Green revolution as a continuous process of change has occurred during 1965-1990 in this region. (IFPRI(2009)).

Apart from technological change mentioned above, there have been some institutional changes in some South and South Asian countries. Policy decisions like restructuring agriculture through land reform is very important for the Asian economies (Economist(2017), Putzel(2000)) has pointed out that land reform has played a pivotal to the Asian development experience of the 20th century. This study has also demonstrated that redistributive efforts in China and Vietnam have supervised to the rapid rise in agricultural productivity of the region as do the partial land reforms in parts of India and the Philippines. Dorner and Thiesenhusen (1990) have established that land reforms in East Asia have widened the domestic market, lessened underemployment and joblessness in both agriculture and industry.

Theoretically, policy and technology play crucial role in enhancing growth of rice production and one can find out through structural break analysis the role of these factors in this context. However, it is important to note that the structural break analysis with reference to rice output level/growth may not be adequate enough to understand the severity of the food crisis that may be resulted in by price shocks. Food crisis may be influenced by either output and/or price shocks. The world experienced the rice crisis in the year 2008 has been due unprecedented price shocks not caused by crop failures in the immediate past but due to policy failures at the government level of the major rice exporting countries. The price spike during the 2007–2008 food crisis was the largest price shock since the world food crisis in 1973–1975 (Timmer and Dawe, 2010). Menelly (2016) explained that the rice crisis in the year 2008 was due to market panic and misguided government actions. At the household level, distributional policy impact of the food crisis in the year 2008 for Philippines, Manzano and Prado(2014) found that the severely affected groups include poor, urban, female-headed, and non-agricultural households.

Considering the issues discussed above this study aims to demonstrate the growth and structural break of rice production for the ten major countries[1] from East, South and South East Asia which account for around 85% to 90% of world rice production for the period 1961 to 2016 by following multiple structural break tests due to Bai and Perron (1998,2001) and examine the role of technological and institutional factors in determining these structural break(s).

This study will enable us to understand the comparative time path and nature of structural break of rice production in each of these countries and see whether any substantive change has occurred during 1961-2016. The paper has been organized as follows. Section 2 describes the data and methodology. Empirical findings are discussed in Section 3. Conclusions are made in Section 4.

2. Data and Methodology

Now we discuss the sources of data and the methodology we have followed in the exercise. This study considers ten major rice producing countries of the South and South East Asia. The data on rice production for all these countries for the period 1961-2016 have been taken from the website of Food and Agricultural Organization(FAO) of the United Nations (www.fao.org). The data on rice (paddy) production quantity is given in tonnes. The longtime period has been chosen considering the availability of the data. China and India are two most important producers of rice throughout the period of our study having 28.49% and 21.43% share of world rice production in 2016 as per the latest FAO data followed by Indonesia (10.43%), Bangladesh(7.11%), Vietnam(5.86%), Myanmar(3.41%),Thailand(3.41%), Philippines(2.38%), Pakistan(1.41%) and Cambodia(1.33%).

The methodology we followed is exploratory in nature and has been univariate time series modelling. First of all, we have used some charts and diagrams for visual inspection of the series considered along with some summary statistics. We have then used all the data in logarithmic scale (natural) for the analysis of growth and structural break. We have checked the stationarity/nonstationarity status of the rice production both at level (logarithmic) and first difference(growth) for each country over 1961-2016 by following unit root test due to Augmented Dickey-Fuller test(ADF) after considering appropriate lag values using information based criteria of a model section. The unit root test is the first step towards determining the stationarity status of the series. We have appropriately taken care of the deterministic part of the series namely constant and/or trend in the ADF equation for carrying out the exercise.

Next, we have tested for the presence of any structural break(s) in each of these series. It is probable that some structural change would lead to permanent change(s)/breaks(s) in the data generating process of the time series either or both at nonstationary and stationary levels. The literature on structural break(s) starting with the classic work by Chow(1960) is vast and comprehensive. The Chow test has a few well-known limitations. Andrews in his seminal work in 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

[1]This study considers China, India, Indonesia, Bangladesh, Vietnam, Myanmar,Thailand, Philippines, Pakistan and Cambodia for the analysis determined on the basis of their share in world rice production. These Asian countries are the major rice producers in the world.

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.

The Bai-Perron multiple breaks point tests have been applied to find structural breaks in all the rice 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 intercept and/or linear trend for each series involved.

3. Empirical Results

We now discuss the empirical results in this section. There are some salient empirical features of the rice economy of this region.

I. The major part of this region except China has been shown as a very serious zone by the Global Hunger Index Report, 2017. There is year to year wide fluctuations in their foodgrains production. Consequently, stability in providing food to their population still remains a formidable challenge.

II. China, despite being the largest producer of rice throughout the period of our study has also become the largest importer of rice since 2013 at present amount being 5,500 thousand metric tonnes in 2017-18 and exhibiting slower growth in recent times with shifting the focus of the economy from agriculture to industry. These countries have achieved marginal self-sufficiency in foodgrains and some countries such as the Philippines and Bangladesh have to depend on large imports.

III. India is the largest exporter of Rice the amount being 12,500 thousand metric tonnes for the year 2016-17 is also the home of the largest number of undernourished population(14.5% of total population).

IV. Production of rice in this region is being constrained by environmental factors such as water sustainability, soil quality and energy-related factors.

Table 1. Profile of Asia's Rural Economy

Country	% of Rural Population(2016)	Employment in agriculture (2016) in %	% of undernourished population(2014-16)#
Bangladesh	64.96%	41.14%	15.1%
Cambodia	79%	27.44%	15.3%
China	43.22%	18.36%	9.6%
India	66.86%	43.44%	14.5%
Indonesia	45.53%	31.80%	7.9%
Myanmar	65.35%	51.3%	16.9%
Pakistan	60.78%	42.27%	19.9%
Philippines	55.71%	27%	13.8%
Thailand	48.46$%	33.3%	9.5%
Vietnam	65.76%	41.87%	10.7%

Source: World Bank; # indicates data from Global Hunger Index(2017).

We now discuss the empirical results following the econometric methodology presented in the preceding section. The structural characteristics of South and South East Asian Countries are briefly presented in Table 1 which show the predominant agro-based character of these economies except China and Thailand to some extent. These countries are also having a significant proportion of the undernourished population as shown in Table 1 as reported in the recently released Global Hunger Index, 2017. We then present in Table 2, the summary statistics of all the rice production series under study at level i.e. in million tonnes. The results show that China has the highest average value followed by India. In actual value, these are 159.091 and 101.519 million tonnes. Although in 1961, China has a slightly higher rice production level with 56.218 million tonnes compared to and India's 53.494 million tonnes (see Figure 1), it has progressed tremendously over time by increasing its productivity and these two countries remained the two major producers of rice in the world throughout the period of our analysis. As far as the values of standard deviations are concerned indicating variability in rice production, we find that China has the highest value of standard deviation at 42.131. In a majority of the countries distributions of rice production are different from the normal distribution as indicated by the values of skewness and kurtosis presented in table 2. We have found from Figure2 that growth rate of rice production for most of the countries as determined by the first logarithmic differences of rice production show stationary movement over time except exhibiting wide fluctuations with Cambodia. The line diagram presented in Figure 3 shows a movement of cropped areas during1961 t0 2016. An important observation from this figure that India has the cropped area even more than China during this period indicating a higher yield for China.

Table 2. Summary Statistics of Annual Rice Production

Rice Producing country	Mean	Median	Standard deviation	Skewness	Kurtosis
Bangladesh	28.337	24.220	12.340	0.732	2.203
Cambodia	3.668	2.562	2.610	1.147	3.119
China	159.091	176.502	42.131	-0.774	2.434
India	101.519	107.050	36.212	0.066	1.635
Indonesia	40.223	43.182	18.872	0.077	1.946
Myanmar	16.400	14.272	7.880	0.595	2.122
Pakistan	5.614	4.991	2.504	0.425	2.397
Philippines	9.916	9.050	4.575	0.456	2.036
Thailand	21.241	19.911	7.835	0.533	2.243
Vietnam	22.261	17.998	12.486	0.502	1.748

Note: Annual Rice production are in million tonnes. Total number of observations for each country is 56.

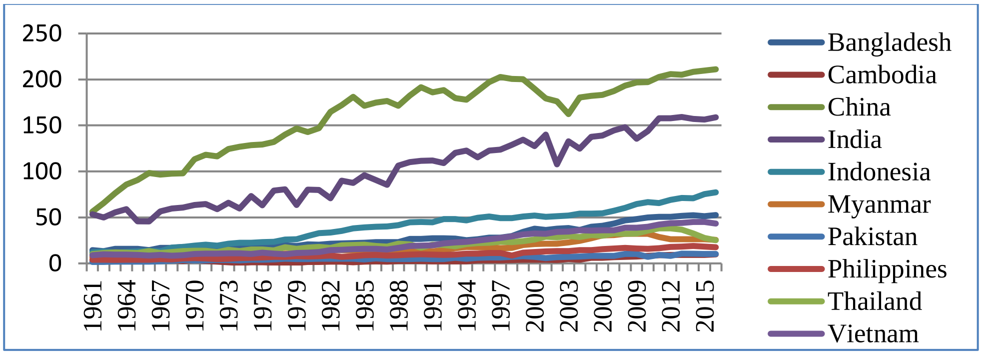

Figure 1. Production of Rice in Million Tonnesof Top Ten Producers in the World(1961-2016)

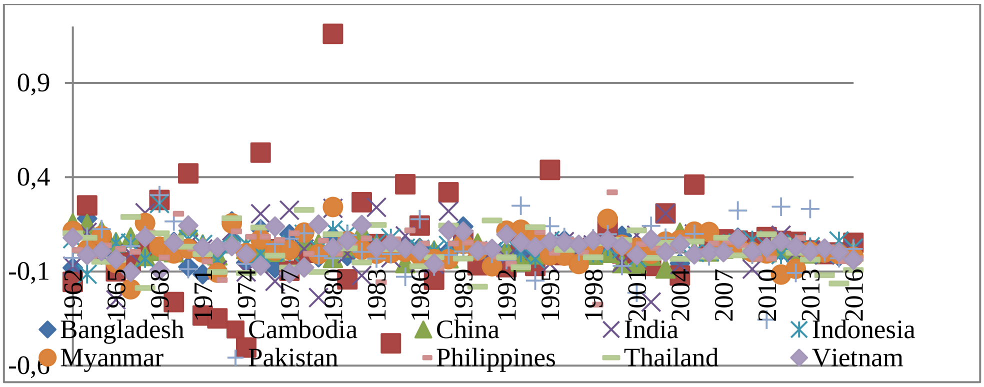

Figure 2. Annual Growth Rate (Continuously compounded) of Rice Production During 1961-2016

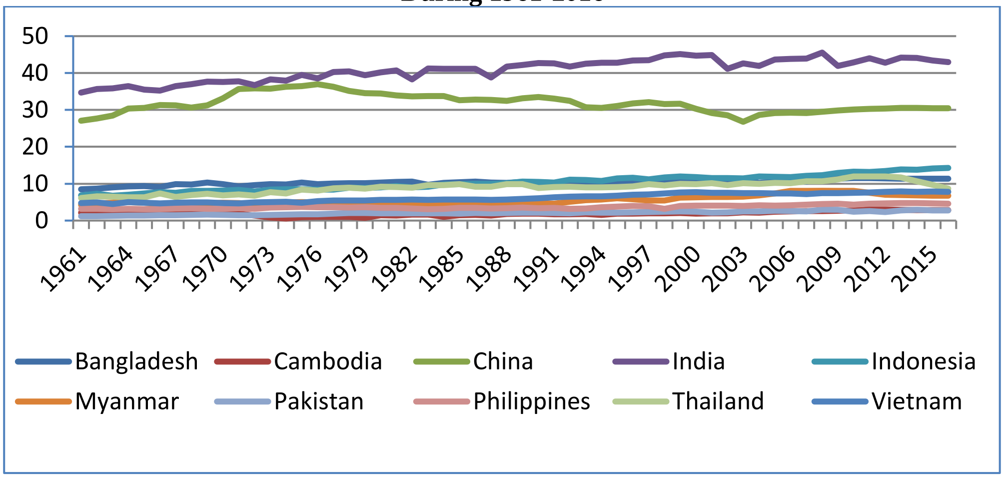

Figure 3 Area Harvested in Million Hectares of Rice During 1961-2016

The results of the ADF tests on all the ten series of rice production are presented in Table 3 below. All the rice production series for ten Asian countries except China and Philippines have been found to be nonstationary at their level (in natural logarithmic) at 5% level of significance values since the null of a unit root cannot be rejected for all these series at this level of significance. Thereafter we tested if these series are stationary at first difference level. It is evident from the ADF test statistics values that all are significant at 1% level, showing thereby that there is no unit root in the first difference series. This also implies that rice production series in most Asian countries are integrated of order 1. We further note that in the deterministic part of the ADF estimating equation, only the intercept is found to be significant at first difference level, which suggests that deterministic trend is significant in level values of all these series.

Table 3. Results of Unit Root Test

Series: Rice production (in natural logarithm)	ADF test statistic value		*p*-value		Deterministic component	
	Level	First diff.	Level	First diff.	Level	First diff.
Bangladesh	-3.487	-9.954	0.051	0.000	constant, trend	constant
Cambodia	-2.419	-9.602	0.366	0.000	constant, trend	constant
China	-4.231	----	0.010	----	constant, trend	-----
India	-3.343	-8.923	0.07	0.000	constant, trend	constant
Indonesia	-1.449	-8.551	0.835	0.000	constant, trend	constant
Myanmar	-1.995	-6.951	0.059	0.000	constant, trend	constant
Pakistan	-3.273	-9.680	0.082	0.000	constant, trend	constant
Philippines	-4.174	-----	0.001	-----	constant, trend	-----
Thailand	-3.254	-10.253	0.085	0.000	constant, trend	constant
Vietnam	-2.417	-8.029	0.367	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.

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 all the 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 each series were obtained along with the estimated break dates. However, at first difference level i.e., for growth series, the null hypothesis could not be rejected for all the ten series except Myanmar implying that there is no evidence of any structural break in any of the growth of rice production of these nine countries. This suggests that rice production levels in all the major Asian countries including China and India have exhibited structural change during this period. Although no significant evidence of structural break has been found for the growth series i.e., logarithmic first differences of rice production for these countries which suggests that the breaks or instability in the time series due to institutional and/or technological change has affected only the trend of the series.

Table 4. Results of UD_{max} and WD_{max} Tests

Series: Rice production (in natural logarithm)	UD_{max} statistic value		WD_{max} statistic value	
	Level	First diff.	Level	First diff.
Bangladesh	656.290*	1.843	1418.136*	2.191
Cambodia	142.506*	3.449	250.039*	3.448
China	146.867*	8.066	206.650*	8.094
India	313.477*	0.590	585.328*	0.849
Indonesia	415.920	4.083	772.283	7.035
Myanmar	372.930*	9.857*	641.215*	11.201*
Pakistan	175.120*	3.173	302.403*	3.173
Philippines	566.051*	2.742	1242.126*	4.807
Thailand	226.255*	3.003	423.014*	3.003
Vietnam	904.928*	4.706	1985.751*	6.690

Note: * indicates significant value at 5% level of significance.

Table 5.Results of the Bai-Perron Multiple Structural Breakpoints Test (Sequential F-Statistic)

Series: Rice production (in natural logarithm)	Total number of break		Actual Break Years	
	Level	First diff.	Level	First diff.
Bangladesh	4	0	1980, 1989, 1998,2007	----
Cambodia	4	0	1972, 1980, 1995, 2005	----
China	4	0	1970, 1978, 1989, 2009	----
India	4	0	1975,1988, 1996, 2005	----
Indonesia	5	0	1969, 1981,1989, 1999, 2007	----
Myanmar	4	1	1972, 1980, 1993, 2004	2009
Pakistan	4	0	1969, 1977, 1996, 2005	----
Philippines	4	0	1975, 1985, 2001, 2009	----
Thailand	4	0	1969, 1978, 1995, 2003	-----
Vietnam	5	0	1970, 1982, 1992, 2000, 2008	-----

Notes: Trimming parameter value is 0.15; level of significance considered is 0.05; different variances in subperiods are allowed

Next, we have examined the break years in terms of structural change in these series at both nonstationary and stationary levels i.e., for both the original and the transformed series by following the multiple structural breakpoints test proposed by Bai and Perron(1998,2001,2003), as discussed in the previous section. We have presented the findings of this test in Table 5 along with the (estimated) break years. Our multiple breakpoint analysis with level values shows that for all the rice production series except Indonesia and Vietnam, the number of breaks obtained in the entire series for each country is 4. For Indonesia and Vietnam, the number of the estimated break years has been found to be 5. It is also important to note that for most of the ten rice production series, this test has found a break year in the late 1960's and early 1970's. The first estimated break year has been found to be 1969 for Indonesia, Pakistan and Thailand, and 1970 for China and Vietnam. The same has been found to be 1972 for Cambodia and Myanmar, and 1975 for India and the Philippines. Only Bangladesh has experienced its first structural break in rice production in the year 1980. We now mention the other break years for the two major rice producing countries in the world namely, China and India. The other break years for China are found to be 1978, 1989 and 2009 whereas for India these are 1988, 1996 and 200 These findings are consistent with the introduction of modern technology in rice production in these countries during 60's and 70's. These results clearly show that this structural break in rice production is due to the so-called Asian Green Revolution in rice. We have also found that no country has experienced any structural break in the growth of rice production during this period except Myanmar in 2009. These results clearly indicate that the effects of technological and institutional change on rice production in most of the Asian countries are not persistent as the structural breaks are only present in level but not in growth.

Table 6A. Regression Results with Structural Break in the Time Series of Rice production of Bangladesh

Time period (Break year)	Country : BangladeshModel AAdj. R^2=0.970			
	Variable	Coefficient	*t*-statistic	*p*-value
1961-1976(1977)	Constant	16.598	533.308	0.000
1977-1988(1989)	Constant	16.876	533.888	0.000
1989-1998(1999)	Constant	17.120	1008.879	0.000
1999-2006(2007)	Constant	17.442	873.713	0.000
2007-2016	Constant	17.720	680.576	0.000
	Country : BangladeshModel BAdj. R^2=0.985			
1961-1998(1999)	Constant	16.434	712.547	0.000
	Linear trend	0.020	21.154	0.000
1999-2007(2008)	Constant	16.529	111.224	0.000
	Linear trend	0.022	6.101	0.000
2008-2016	Constant	17.071	140.485	0.000
	Linear trend	0.013	5.54723	0.000

Notes: Trimming parameter value is 0.15.

Table 6B. Regression Results with Structural Break in the Time Series of Rice production of Cambodia

Time period (Break year)	Country : CambodiaModel AAdj. R^2=0.906			
	Variable	Coefficient	*t*-statistic	*p*-value
1961-1971(1972)	Constant	14.786	274.756	0.000
1972-1979(1980)	Constant	13.791	119.923	0.000
1980-1994(1995)	Constant	14.525	200.240	0.000
1995-2004(2005)	Constant	15.162	325.580	0.000
2005-2016	Constant	15.901	204.494	0.000
	Country : CambodiaModel BAdj. R^2=0.923			
1961-1972(1973)	Constant	14.686	196.512	0.000
	Linear trend	0.011	0.758	0.452
1973-2016	Constant	12.867	136.286	0.000
	Linear trend	0.059	26.397	0.000

Notes: Trimming parameter value is 0.15.

Table 6C. Regression Results with Structural Break in the Time Series of Rice production of China

Time period (Break year)	Country : ChinaModel AAdj. R^2=0.905			
	Variable	Coefficient	*t*-statistic	*p*-value
1961-1969(1970)	Constant	18.242	193.569	0.000
1970-1980(1981)	Constant	18.672	492.791	0.000
1981-1985(1986)	Constant	18.932	523.719	0.000
1986-2008(2009)	Constant	19.033	1153.871	0.000
2010-2016	Constant	19.136	1491.704	0.000
	Country : ChinaModel BAdj. R^2=0.967			
1961-1972(1973)	Constant	17.939	234.167	0.000
	Linear trend	0.060	6.983	0.000
1973-2000(2001)	Constant	18.455	314.450	0.000

	Linear trend	0.018	9.077	0.000
2001-2016	Constant	18.350	233.064	0.000
	Linear trend	0.015	9.632	0.000

Notes: Trimming parameter value is 0.15

Table 6D. Regression Results with Structural Break in the Time Series of Rice production of India

Time period (Break year)	Country : IndiaModel AAdj. R^2=0.935			
	Variable	Coefficient	*t*-statistic	*p*-value
1961-1974(1975)	Constant	17.853	425.257	0.000
1975-1987(1988)	Constant	18.190	401.634	0.000
1988-1995(1996)	Constant	18.546	890.270	0.000
1996-2006(2007)	Constant	18.673	962.636	0.000
2007-2016	Constant	18.838	781.927	0.000
	Country : IndiaModel BAdj. R^2=0.963			
1961-1987(1988)	Constant	17.681	444.550	0.000
	Linear trend	0.024	10.807	0.000
1988-2001(2002)	Constant	17.962	471.923	0.000
	Linear trend	0.019	16.796	0.000
2002-2016	Constant	17.737	87.956	0.000
	Linear trend	0.021	5.3167	0.000

Table 6E. Regression Results with Structural Break in the Time Series of Rice production of Indonesia

Time period (Break year)	Country : IndonesiaModel AAdj. R^2=0.973			
	Variable	Coefficient	*t*-statistic	*p*-value
1961-1968(1969)	Constant	16.393	342.382	0.000
1969-1979(1980)	Constant	16.900	319.442	0.000
1980-1988(1989)	Constant	17.412	323.751	0.000
1989-1998(1999)	Constant	17.680	837.647	0.000
1999-2008(2009)	Constant	17.797	720.584	0.000
2009-2016	Constant	18.063	574.785	0.000
	Country : IndonesiaModel BAdj. R^2=0.963			
1961-1980(1988)	Constant	16.197	370.936	0.000
	Linear trend	0.050	17.054	0.000
1981-1991(1992)	Constant	16.624	255.963	0.000
	Linear trend	0.033	13.772	0.000
1992-2006(2007)	Constant	17.381	523.903	0.000
	Linear trend	0.010	10.880	0.000
2007-2016	Constant	16.460	142.109	0.000
	Linear trend	0.030	14.024	0.000

Notes: Trimming parameter value is 0.15

Table 6F. Regression Results with Structural Break in the Time Series of Rice production of Myanmar

Time period (Break year)	Country : MyanmarModel AAdj. R^2=0.955			
	Variable	Coefficient	*t*-statistic	*p*-value
1961-1979(1980)	Constant	15.933	392.530	0.000
1980-1992(1993)	Constant	16.448	1613.200	0.000
1993-2003(2004)	Constant	16.756	313.849	0.000
2004-2016	Constant	17.157	440.328	0.000
	Country : MyanmarModel BAdj. R^2=0.980			
1961-1971(1972)	Constant	15.806	367.206	0.000
	Linear trend	0.010	2.086	0.042
1972-1986(1987)	Constant	15.263	179.184	0.000
	Linear trend	0.051	9.563	0.000
1987-2005(2006)	Constant	15.321	147.905	0.000
	Linear trend	0.038	13.570	0.000
2006-2016	Constant	18.422	77.014	0.000
	Linear trend	-0.024	-5.461	0.000
	Country : MyanmarModel CAdj. R^2=0.063			
1962-2008(2009)	Constant	0.032	3.187	0.000
2009-2016	Constant	-0.028	-1.815	0.000

Notes: Trimming parameter value is 0.15.

Table 6G: Regression Results with Structural Break in the Time Series of Rice production of Pakistan

Time period (Break year)	Country : PakistanModel AAdj. R^2=0.947			
	Variable	Coefficient	*t*-statistic	*p*-value
1961-1968(1969)	Constant	14.519	168.760	0.000
1969-1976(1977)	Constant	15.10	482.188	0.000
1977-1994(1995)	Constant	15.410	996.973	0.000
1995-2004(2005)	Constant	15.731	512.690	0.000
2005-2016	Constant	16.040	388.624	0.000
	Country : PakistanModel BAdj. R^2=0.971			
1961-1968(1969)	Constant	14.194	291.844	0.000
	Linear trend	0.072	5.353	0.000
1969-1976(1977)	Constant	14.816	150.349	0.000
	Linear trend	0.023	2.955	0.000
1977-1984(1985)	Constant	15.104	156.307	0.000
	Linear trend	0.015	3.025	0.004
1985-1992(1993)	Constant	15.346	76.269	0.000
	Linear trend	0.002	0.210	0.000
1993-2016	Constant	14.682	135.143	0.000
	Linear trend	0.027	11.106	0.000

Notes: Trimming parameter value is 0.15.

Table 6H. Regression Results with Structural Break in the Time Series of Rice production of Philippines

Time period (Break year)	Country : Philippines Model AAdj. R^2=0.944			
	Variable	Coefficient	*t*-statistic	*p*-value
1961-1974(1975)	Constant	15.335	263.301	0.000
1975-1984(1985)	Constant	15.813	396.376	0.000
1985-1992(1993)	Constant	16.035	784.238	0.000
1993-2003(2004)	Constant	16.241	298.635	0.000
2004-2016	Constant	16.629	451.589	0.000
	Country : PhilippinesModel BAdj. R^2=0.978			
1961-1982(1983)	Constant	15.052	480.454	0.000
	Linear trend	0.034	18.750	0.000
1983-2016(1977)	Constant	15.210	321.505	0.000
	Linear trend	0.028	25.152	0.000

Notes: Trimming parameter value is 0.15.

Table 6I. Regression Results with Structural Break in the Time Series of Rice production of Thailand

Time period (Break year)	Country : Thailand Model AAdj. R^2=0.930			
	Variable	Coefficient	*t*-statistic	*p*-value
1961-1968(1969)	Constant	16.270	637.202	0.000
1969-1977(1978)	Constant	16.453	762.604	0.000
1978-1994(1995)	Constant	16.751	643.723	0.000
1995-2002(2003)	Constant	17.021	331.225	0.000
2003-2016	Constant	17.280	375.554	0.000
	Country : ThailandModel BAdj. R^2=0.965			
1961-1989(1990)	Constant	16.159	987.341	0.000
	Linear trend	0.024	24.123	0.000
1990-2000(2001)	Constant	15.708	165.016	0.000
	Linear trend	0.034	12.865	0.000
2001-2008(2009)	Constant	16.463	152.888	0.000
	Linear trend	0.017	7.069	0.000
209-2016	Constant	19.506	18.218	0.000
	Linear trend	-0.042	-2.059	0.000

Notes: Trimming parameter value is 0.15.

Table 6J. Regression Results with Structural Break in the Time Series of Rice production of Vietnam

Time period (Break year)	Country : VietnamModel AAdj. R^2=0.979			
	Variable	Coefficient	*t*-statistic	*p*-value
1961-1969(1970)	Constant	16.027	679.054	0.000
1970-1981(1982)	Constant	16.207	794.005	0.000
1982-1991(1992)	Constant	16.622	316.309	0.000
1992-1999(2000)	Constant	17.064	267.682	0.000
2000-2007(2008)	Constant	17.361	768.431	0.000
208-2016	Constant	17.560	592.559	0.000
	Country : VietnamModel BAdj. R^2=0.994			
1961-1969(1970)	Constant	16.091	494.657	0.000

	Linear trend	-0.013	-2.660	0.000
1970-1981(1982)	Constant	16.048	263.159	0.000
	Linear trend	0.010	2.236	0.000
1982- 1989(1990)	Constant	15.797	102.394	0.000
	Linear trend	0.031	4.766	0.000
1990-1998(1999)	Constant	15.163	402.656	0.000
	Linear trend	0.053	50.738	0.000
1999-2016	Constant	16.396	258.120	0.000
	Linear trend	0.022	15.621	0.000

Notes: Trimming parameter value is 0.15.

Looking at the estimated coefficients as presented in Tables 6A to 6J, we note that for all the ten models the constant and time trend has been found to be significant for all the series and determine the nature of the structural break.We have considered Heteroscedasticity and autocorrelation (HAC) adjusted standard errors and covariances following the Newey-West method in each estimation. It has also been allowed heterogeneous error distributions across breaks and this has been followed for all the tables 6A to 6J. It is found from these results that in most of the cases structural break has been in terms of intercept and in few cases, it has been in terms of time trend. It is important to note that the estimated results presented in each table consider the break in level (natural logarithm) of rice production series for the corresponding country following the OLS method of estimation using Eviews 9.0 software. We have found from Table 6A that for Bangladesh structural breaks in levels of rice production have occurred in terms of positive changes in the intercept in the post-break period compared to the pre-break period for all the breakpoints. The time trend break has occurred in 1999 and 2008. Considering the break year 1999 we find that the coefficient value of linear trend has slightly increased in the post- break period (1999-2007) to 0.022 from 0.020, the pre-break period (1961-1998). However, it has fallen to 0.013 after the break year 2008. Further, all the remaining nine series are found to have the increased coefficient value associated with the intercept in the post-break period compared to pre-break period implying a strong effect of structural factors (technological and/or institutional) in pushing up the level values of the series. The linear trend, however, was not equally responsive for all the ten series. For example in China, the linear trend coefficient value has consistently fallen in the post-break period from the pre-break period and it is true for the trend break years 1973 and 2001. India has, however, mixed results for the break years 1988 and 2002. The trend break year 1988 has led to having a strong negative impact on India's rice production whereas the year 2002 has a positive impact. But the most interesting observations are experienced in case of Myanmar, Thailand and Vietnam in the years 2009, 2009 and 1970, respectively, where the linear trend coefficient turns out to be negative in the post-break period compared to the pre-break period. These structural changes may be associated with major political/policy changes that took place in those years for the countries concerned. Finally, it may be noted that the same test was also applied to all the series at the stationary level, and in all cases, except Myanmar, no break in the stationary series was found.

4. Conclusions

Rice is still the leading cereal in the human food system and the major source of energy for billions of human population in Asia. It is quite different from other cereal crops as it exhibits high volatility in prices due to its concentration of production and consumption in Asia and thin international trade. Considering annual rice production for the ten major Asian countries for the period 1961-2016, this paper has carried out an exploratory time series analysis to study the presence of multiple structural break, if any, on these series both at the level and in growth.. The findings show that most of the time series are integrated of order one implying that these time series are nonstationary at the level values but stationary at first difference. The tests for the existence of multiple structural breakpoints in a time series show that there exists more than one break at level values, but none at first difference level except Myanmar. It has also been found that Asian green revolution along with institutional reforms has played a key role in pushing up the level of the output of rice production but these changes could not impact on growth acceleration of this crop. Overall, it may be concluded that this study of structural change involving rice production of the World's major rice producers using multiple break analysis show that some structural changes have taken place in the short-run but it has not made a profound impact on any of these series in the long run. We also understand from this analysis that policy and technology have played crucial role in explaining structural break of rice production in the major rice producing countries of the world. Further, it is observed from the analysis that some of the structural break years in the early 1970's and the period during 2007-2009 are consistent with the major food crisis that the world experienced in the last 50 years.

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