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Beta-convergence of crop yield across countries: A Modern Panel Data Analysis

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Research Article

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Abstract

This study examines the state of beta-convergence in three major crop yields l in the world namely rice, wheat and maize in terms of output production and cereal grain consumption during the period 1961 to 2016 using modern panel data approach concerning beta convergence. This has been done by applying the advanced panel data methodology, namely, panel unit root tests on demeaned series and panel regression apart from conventional indicators such as standard deviation and coefficient of variation. The conventional sigma convergence indicators namely, standard deviation and coefficient of variation show convergence for wheat for the period of 1986 to 2016 showing a downward trend and thus indicating sigma-convergence, But the results of panel unit root and panel regression establish beta convergence for all the crop yield. This result also shows that economies converge to different steady states.

JEL classification: Q1, Q18, C23, O47

1. Introduction

Over the last fifty years global population has increased at a lower rate compared to the growth of major cereals production(2.1% on an average) (Beddow et al.(2014)). This growth in cereal production has been possible due to unprecedented growth of crop yield (Pandey (et al. 2012)). This has been highly possible due to technological change and large investment in agricultural R & D (Alston et al.(2013)). However, the period of global cereal abundance may not be sustainable. In view of rising population combined with increased income, non-food demand for cereals such as bio fuels demonstrate a significant increase in demand for cereals. Therefore, there are obvious issues to understand how and where this additional burden of cereals demand can be met in the presence of several natural (land and water) and environmental constrains(climate change).

There are some works where emphasis has been given to meeting yield gap to resolve food scarcity issue. However, in our approach we intend to find out the state of convergence of major crop yield and thus focus on the possibilities of increasing yield rates of the low yield countries through technological and innovative measures so that the food security problem can be resolved on earth.

Again, agriculture is still the mainstay of economic life for millions of rural population leaving in major parts of the poor countries. It is estimated to account for 29.5 percent of global employment and 68.5 percent of employment in low-income countries (World Bank (2014)). Agriculture growth has been found to be pro-poor in the sense that it is more effective in reducing poverty compared to growth in elsewhere(World Bank (2008)). Since differences in agricultural productivity account for a large share of aggregate productivity variation across countries, so policies towards reducing agricultural productivity differences can be highly effective in reducing regional inequality across countries.

Considering the combined harvest of 2.5 around 2.5 billion tonnes, rice, wheat and maize are the world's most widely cultivated crops and the foundation of world food security. In human diet these three crops contribute around 42% of the world's calorie supply. The contribution to protein supply is the second largest(around 37%) after Fish and livestock products (FAO, 2016). Geographically, except Latin America these cereals provide with more protein than meat, fish, milk and eggs combined. Historically, agriculture has played significant role, particularly these cereals in building and collapsing of several great civilizations of the humanity. In modern time to meet the growing challenges of ever increasing population, high increases in productivity were achieved through the use of heavy farm machinery powered by fossil fuel, along with high-yielding crop varieties, irrigation and agrochemicals (FAO, 2011).

So considering the importance of cross-country agricultural productivity or yield differences in terms of food security, poverty reduction and removal of overall inequality, we attempt to understand the state of cross-country crop-yield differences over time.

The literature on convergence empirics is very comprehensive(See for details Quah(1996)). Following the seminal contributions of Barro(1990) and Mankiew et al.(1992), a large number of empirical cross-country analysis of growth and development have taken place. The standard cross-country growth regression framework and its panel cousin have been used in the econometric literature although the 'growth regression approach' came under attack from several corners but it still has life in it.

This paper is intended to study the crop yield convergence with reference to beta convergence of most three important crops in terms of consumption and production in the world viz., rice, wheat and maize during a long time series data and applying modern panel data approach including dynamic panel data analysis. In order to address this empirical question of major crop yield convergence, we have identified the period(sub-period) during which, both sigma-convergence and beta convergence, that are commonly used in such analyses, are achieved. Apart from using dispersion measures for sigma-convergence, presence of beta convergence has been examined by using the standard panel unit root tests of the demeaned productivity series in logarithm, static panel regression.

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

2. Data And Econometric Methodology

The data reported under the element yield represents the harvested production per unit of harvested cropped area for each crop. The data on crop yield (also called productivity) (unit: hectogram/hectare) has been defined here as output per unit of cropped area (hg/ha) for each major crop namely rice, wheat, maize for all the countries during the period 1961 to 2016, have been collected from the FAOSTAT of the (www.faostat.com) of the Food and Agricultural Organization (www.fao.org). Considering the availability of data during this period, we have chosen 99 countries for rice yield, 86 countries for wheat yield and 130 countries for maize yield.

2.2 Econometric Methodology

Two concepts of the convergence hypothesis, namely, sigma convergence and beta-convergence, exist in the literature. In the context of crop yield, sigma convergence occurs when cross-sectional dispersion measured by the standard deviation and/or coefficient of variation of the logarithm of crop yield across the countries tends to decline over time. This can be verified by running a regression of either or both of the cross-sectional dispersion measures over time. The Bai-Perron multiple breaks point test (Bai Perron(1998) 2001) has been applied to find structural breaks in these regressions to examine whether there is a sustained upward or downward trend.

The other notion of convergence i.e., beta-convergence, applies when a poor country tends to 'catch up' the richer ones in terms of average yield. Sala-i-Martin (1996) pointed out that beta convergence is necessary but not a sufficient condition for achieving sigma convergence. Beta convergence is necessary but not sufficient condition for sigma convergence (Paas and Schlitte, 2006). According to Monfort (2008, p.3), this happens "either because economies can converge towards one another but random shocks push them apart or because, in the case of conditional Beta-convergence, economies can converge towards different steady states. A modelling approach to beta convergence has come across several stages from the conventional cross-sectional regression to dynamic panel models.

In this study, we first investigate unconditional or absolute beta-convergence which assumes structurally homogeneous cross section units (countries, in this study).For testing unconditional beta convergence we have followed the panel unit root approach. Defining y_{kit} to be ln(Y_{kit}) where Y_{kit} is the crop yield of the k th crop(k=1,2,3 for rice, wheat and maize , respectively) in the i th country at t th time point(i.e., year), the panel unit root tests on the demeaned series($\widetilde{y}_{kit} = y_{kit} - \overline{y}_{kt}$) of y_{kit},where $\overline{y}_{kt} = \frac{1}{n}\sum_{i=1}^{n} y_{kit}$, proposed by Levin *et al*. (2002) , Im *et al*. (2003), and Maddala and Wu (1999) , have been applied (see, Mukhopadhyay and Sarkar (2015) for a brief description of these tests).

The static panel regression approach that is followed in our analysis for testing conditional beta convergence in the *k*th (k=1,2,3) crop yield considers the following regression equation:

$$\ln(\frac{Y_{kit}}{Y_{ki,t-1}}) = \mu_{ki} + \beta \ln Y_{ki,t-1} + + \varepsilon_{kit}, k = 1,2,3 \qquad (1)$$

where *k*th crop yield in the country i attime t is represented by Y_{kit}. If β is significant and negative then the resultant conditional convergence holds. The state specific fixed effect is captured by μ_{ki}. The Hausman specification test has been applied to decide between fixed effect model and random effect model. Further, the White's heteroscedasticity consistent sampling variances and covariances have been used in the estimationresults.

3. Results And Discussion

Now, we report the results of structural break tests on the above estimated regressions in Table 1 by following Bai-Perron multiple structural break test. By applying the $UD_{\max}$ and $WD_{\max\ x}$ tests, it is found that the null hypothesis of ‘no break’ is rejected in favour of ‘two break’ for the series of standard deviation and coefficient of variations rice yield, “one break’ for the series of standard deviation and coefficient of variation of wheat yield. But the null of ‘no break’ cannot be rejected for the sd and cv of the maize yield series. Once break years are determined, we run regression incorporating these breaks as shown in Table 2 below and found that the series of standard deviation and coefficient of variation of wheat experiences a downward trend after 1986 indicating ‘sigma convergence’ for the wheat yield series for the period 1986 to 2016. However, rice yield series does not experience any change in its trend behavior indicating absence of sigma convergence for this series.

Table 1
Results of UD_{max} and WD_{max} Tests

Series	**UD_{max} statistic value**		**WD_{max} statistic value**	
	Standard deviation	Coefficient of variation	Standard deviation	Coefficient of variation
Rice yield	31.804**	31.947**	54.285**	54.956**
Wheat yield	52.824**	43.817**	52.82**	43.817**
Maize yield	8.415	8.348	10.917	10.910
*Note: * indicates significant value at 5% level of significance.*				

Table 2
Regression Results with Structural Break in the Time Series of Cross-sectional standard deviation and coefficient of variation

Time period (Break year)	Rice Yield Standard Deviation(Cross sectional) Adj. R^2 = 0.794			
	Variable	Coefficient	*t*-statistic	*p*-value
1961–1985(1986)	Constant	0.552	68.763	0.000
	Linear trend	0.002	3.237	0.002
1986–1994(1995)	Constant	0.402	5.609	0.000
	Linear trend	0.006	2.289	0.027
1995–2008(2009)	Constant	0.198	3.843	0.000
	Linear trend	0.010	8.273	0.000
2009–2016	Constant	0.319	2.108	0.040
	Linear trend	0.006	2.139	0.038
Time period (Break year)	Rice Yield Coefficient of variation(Cross sectional) Adj. R^2 = 0.629			
	Variable	Coefficient	*t*-statistic	*p*-value
1961–1985(1986)	Constant	0.056	62.198	0.0000
	Linear trend	0.0001	1.753	0.086
1986–2008(2009)	Constant	0.038	15.401	0.000
	Linear trend	0.0006	8.374	0.000
2009–2016	Constant	0.033	1.934	0.059
	Linear trend	0.0006	1.675	0.100
Time period (Break year)	Wheat Yield Standard deviation(Cross sectional) Adj. R^2 = 0.595			
	Variable	Coefficient	*t*-statistic	*p*-value

Notes: Trimming parameter value is 0.15.

Time period (Break year)	Rice Yield Standard Deviation(Cross sectional) Adj. $R^2 = 0.794$			
1961–1985(1986)	Constant	0.570	44.549	0.000
	Linear trend	0.007	7.543	0.000
1986–2016	Constant	0.737	29.523	0.000
	Linear trend	-0.001	-1.835	0.072
Time period (Break year)	Wheat Yield Coefficient of variation(Cross sectional) Adj. $R^2 = 0.440$			
	Variable	Coefficient	*t*-statistic	*p*-value
1961–1985(1986)	Constant	0.061	45.367	0.000
	Linear trend	0.0006	5.973	0.000
1986–2016	Constant	0.077	29.135	0.000
	Linear trend	-0.0002	-2.979	0.004
Notes: Trimming parameter value is 0.15.				

As already discussed in the previous section, the other important measure of convergence i.e., beta-convergence, implies crop yield in countries with low initial level yield tends to increase at a faster rate than high crop yield level countries. The panel data approach of beta convergence first uses the panel unit root test on the demeaned series of the logarithm of productivity level. The results of this test are presented in Table 3.

The null hypothesis in case of panel unit root tests assumes unit root i.e., nonstationarity of the panel. The values of the LLC (due to Levin et al. (2002)) test statistic for crop yield of rice, wheat and maize are − 7.939, -18.295 and − 7.947, respectively, which are highly significant at 1% level of significance, and hence the null of nonstationarity is rejected in favour of stationarity in the demeaned series for all these three crops. Thus it is concluded that based on the results of this test, crop yield shows convergence across the globe for all the three principal cereal crops. The same conclusion is also drawn from the IPS(due to Im et al. (2003)) test, the Fisher's chi-square (ADF version), and Fisher's chi-square(PP version) tests since values of all these test statistics are highly significant. In all these tests we have used Schwartz's Bayesian information criterion (BIC) for lag selection. Thus all the panel unit root tests infer stationarity in the demeaned series of the logarithm of crop yield of rice, wheat and maize. Hence we conclude that beta-convergence in cereal yield holds across the globe.

Table 3
Panel unit root test results on demeaned series

Series: Rice Yield (99 Countries; Time 1961–2016)		
Panel unit root test	Test statistic value	*p*- value
Levin-Lin-Chu unit-root test (LLC)	-7.939	0.000
Im-Pesaran-Shin unit-root test (IPS)	-11.198	0.000
Fisher-Chi-square test (ADF)	573.787	0.000
Fisher-Chi-square test (PP)	652.348	0.000
Series: Wheat Yield (86 Countries; Time 1961–2016)		
Panel unit root test	Test statistic value	*p*- value
Levin-Lin-Chu unit-root test (LLC)	-18.295	0.000
Im-Pesaran-Shin unit-root test (IPS)	-32.088	0.000
Fisher-Chi-square test (ADF)	1273.89	0.000
Fisher-Chi-square test (PP)	1801.72	0.000
Series: Maize Yield (130 Countries; Time 1961–2016)		
Panel unit root test	Test statistic value	*p*- value
Levin-Lin-Chu unit-root test (LLC)	-7.947	0.000
Im-Pesaran-Shin unit-root test (IPS)	-12.894	0.000
Fisher-Chi-square test (ADF)	835.180	0.000
Fisher-Chi-square test (PP)	921.652	0.000

The results of beta convergence are reported by using the static panel regression model in Table 7. As our beta convergence is essentially absolute in nature we do not consider any explanatory variable(s) for capturing cross-sectional heterogeneity. To be specific, for the purpose of testing for beta-convergence, we have used the regression equation in (1) where the logarithm of the initial yield level has been taken as the regressor. Obviously, the beta convergence here is absolute. In Table 4, we first present the panel regression results for rice yield. In this regression the beta coefficient is found to be highly significant and negative (-15.071), implying thereby an inverse relationship in yield growth and its initial level. We also obtained analogous results for wheat and maize yield. The corresponding test statistic values for these two yield crops are – 14.555 and – 14.172 These findings thus confirm beta convergence. We have also carried out the Hausman specification test for deciding between a fixed effect model and random effect model in the static panel data analysis for each crop yield. We find from Table 5 that the chi-square test statistic values for these three equations are 141.057, 131.685 and 40.262 which are highly significant at 1% level of significance. This implies the rejection of the random effect model in favour of the fixed effect model for each series. Accordingly, the fixed effect model has been used. In order to take care of the possible cross-sectional heterogeneity, we have used White's heteroscedasticity consistent variances and covariances in estimation.

Table 4
Results on absolute beta convergence

Dependent Variable:				
Variable	Coefficient	Standard error	*t*-statistic	*p*-value
Constant	2.102	0.139	15.09	0.0000
	-0.206	0.014	-15.071	0.0000
Hasusman Test statistic = 141.057#, Adj. R^2 = 0.098				
Dependent Variable:				
Constant	3.043	0.208	14.605	0.0000
	-0.309	0.021	-14.555	0.0000
Hasusman Test statistic = 131.685#, Adj. R^2 = 0.165				
Dependent Variable:				
Variable	Coefficient	Standard error	*t*-statistic	*p*-value
Constant	2.070	0.146	14.217	0.0000
	-0.209	0.015	-14.172	0.0000
Hasusman Test statistic = 40.262#, Adj. R^2 = 0.094				
# denotes the test statistic is significant at 1% level of significance.				

4. Summary And Conclusions

This study investigates the convergence hypothesis in the crop yield (in terms of output per unit of cropped area) of major cereals in the world namely rice, wheat, maize during the period 1961 to 2016 across the globe using the concept of beta convergence. This has been done by applying the modern econometric tools available for panel data analysis, namely, panel unit root tests on demeaned series, static panel regression apart from structural break point analysis due to Bai-Perron on conventional measures based on standard deviation and coefficient of variation.

The panel unit root test on the demeaned productivity (logarithmic) series is found to be stationary by all the standard tests. This evidence found is thus in favour of (absolute) beta convergence. The static panel regression shows an inverse relationship between growth rate and lagged dependent variable implying a conditional beta-convergence in the series

Finally, this empirical evidence on convergence in crop yield of major cereals demonstrates that these countries converge to their own steady state equilibrium although no negative trend is profoundly present in terms of declining yield-gap across the countries except wheat yield which experiences a downward trend after 1986. Further, analysis of club convergence is necessary for better understanding of this very important issue in world agriculture. It may be pointed out that it is possible to reduce rural poverty in the developing world by reducing productivity gaps in major cereal yield.

Stagnating or declining crop yields along with environmental degradation and climate change are threatening global food security, in particular, in developing regions. But at the same time protecting natural resources are utmost important for sustainable development. Therefore, sustainable crop intensification is need of the hour.

Declarations

The corresponding author declares no potential conflict of interest.

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