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CONVERGENCE OF FOODGRAINS PRODUCTION ACROSS INDIAN STATES: A STUDY WITH PANEL DATA

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Abstract: This paper attempts to understand the regional convergence—both in terms of sigma and beta convergences—of per capita foodgrains production across the major foodgrains producing states of India over the period 1991–92 to 2011–12, by applying the conventional methods as well as the modern panel model approach for convergence hypothesis. While the former do not suggest sigma convergence, beta convergence is empirically established by the latter methods. Further, the paper also examines the convergence of per capita cereal consumption, and finds some evidence of beta convergence for rural consumption but not for urban consumption.

Key words: per capita foodgrains output, sigma convergence, beta convergence, panel unit root tests, dynamic panel.

JEL Classification Number: Q1, Q18, C23, O47.

1. INTRODUCTION

Despite the structural transformation of the Indian economy from an agro-based state to a service oriented economy during the last couple of decades, millions of rural people in India are still dependent on this primary sector for their livelihood. The employment in the agriculture and allied sector as share of total workers is 55% as per 2011 Census as against 58.2% in 1991. Further, in accordance with the 2011 Census figures, about one in two males and two of every three females are engaged in agricultural activities either

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as cultivators or as agricultural labourers. However, the GDP share of agriculture has come down from 33.3% in 1990–91 to 13.9% in 2011–12. This income-employment contrast exhibits the distress economic life of small cultivators and agricultural workers in India.

In Indian agriculture foodgrains is the most important item in terms of production, rural employment and household consumption. There has been remarkable progress in some parts of India in foodgrains production in the post-green revolution era.[1] The growth in total foodgrains production during the period from 2000–01 to 2011–12 has been 2.32% as against 2.02% in the previous decade. However, this growth has not been achieved uniformly by all the regions (states) which is essential for the overall rural development of the country. Among the 15 major Indian states, three largest foodgrains producing states, *viz.*, Uttar Pradesh, Punjab and Madhya Pradesh had 37.94% share in total foodgrains production in 2011–12 (see, for details, Economic Survey of India, 2012–13). In addition to technological know-how and institutional factors, inequality to have access to information in terms of crop cultivation, water management and climate change are becoming important in the regional variations of crop yields leading to unequal distribution of per capita foodgrains production.

Apart from foodgrains production which has huge positive implications in local employment and which is the dominant source of rural income, foodgrains consumption is also important in the overall consumption of the rural people. The 66th Round NSSO data on household consumption show that the rural foodgrains expenditure had 36% share in total food expenditure in 2009–10. In view of this importance of foodgrains in rural employment, income generation and consumption along with the presence of state level inequality in its production, it would be worthwhile and interesting to investigate the regional convergence of per capita production and consumption across the states of India.

An important recent facet of progress in agriculture at the macro level in India has been its self sufficiency in foodgrains during the last two decades. As per the Economic Survey of the Government of India, 2011–12, India has been consistently performing as a net exporter of foodgrains since 1995. India's population has increased from 551.3 millions in 1971 to 1169.4 millions in 2009 whereas its foodgrains production has increased from 94.9 million tonnes to 205.2 million tonnes during the same period. This growth in foodgrains has been possible due to introduction of the New Agricultural Strategy in 1966–67 and some structural reforms which were carried out in the early 1980's in some parts of the country (see, for details, Tripathi and Prasad (2009)).

Self-sufficiency in production of foodgrains is often advocated as a first step towards attaining food security for a country of India's size (see, for details, 9th Five year Plan Document, Vol. 2). Moreover, increase in the per capita availability of foodgrains and its proper distribution can properly address the collective problem of extreme poverty,

[1] India achieved significant improvement in foodgrains production in mid- 1960's, and this period is often referred to as the period of green revolution in India.

nutrition and hunger in a country like India which is home to the largest number of food-insecure people in the world (FAO Reports, 2008). Since foodgrains production is still the major source of livelihood for a large section of peasant cultivators and agricultural labourers in a country like India, the process of production of foodgrains in this predominantly small-holding agricultural economy ensures employment, income as well as food security simultaneously for these sections of people.

In its report in February 2009, the International Food Policy Research Institute (IFPRI) has clearly indicated the extent of disparity among the Indian states in terms of food and nutrition, as represented by the 'hunger index'.[2] In terms of this index, Punjab has the lowest score of 13.63 (i.e., it is the lowest hunger state in India) whereas the highest index score, 30.8, is for Madhya Pradesh which signifies the extent of disparity among the states.

There has been serious uneven growth of foodgrains and agricultural output since independence across different parts of India (see Drèze *et al.* (2006)). During 2002 to 2011, the three states of Uttar Pradesh, Punjab and Madhya Pradesh together had, on an average, 42% share in the total foodgrains production of the country while their total population was 27% as per 2011 Census. It is only in case of five states that the foodgrains shares have exceeded their shares in the all-India population during this period. Moreover, impressive growths in foodgrains and agricultural output have profound implications in terms of rural income and employment generation as it is often observed that large non-irrigated cultivated tracts have experienced virtual stagnation against a background of rapidly growing population in recent years (see, for details, Drèze *et al.* (2006)).

The empirical literature on convergence hypothesis of neoclassical growth of income and consumption has developed substantially since the seminal works of Barro and Sala-i-Martin (1992) and Mankiw *et al.* (1992). There are two basic concepts of convergence, namely, 'sigma convergence' and 'beta convergence'. The first notion of convergence i.e., the 'sigma convergence' occurs if the dispersion of per capita economic levels (in logarithmic values) represented by income, consumption, or output across a group of economies or regions declines over time. The other notion of convergence i.e., the 'beta convergence', is satisfied when a poor economy/region tends to grow faster than the rich one, and this convergence is obtained if the regression of average (over a period of time) income/output growth on initial income/output level has a significant negative slope coefficient.

It may be interesting to note that evidence for convergence of economic growth in terms of these two concepts is not necessarily uniform in case of many countries for which such studies have been undertaken. For example, in case of the U.S.A., many studies such as those by Evans and Karras (1996a, 1996b), Sala-i-Martin (1996), and Evans (1997a, 1997b) found beta convergence in per capita log income among the states of the U.S.A., but Tsionas (2000) found that sigma convergence does not hold for the

[2] 'Hunger Index' is an index of severity of hunger based on inadequate consumption, child underweight and child mortality.

US states over different periods.

Quite a few such studies have also been conducted for understanding regional convergence of per capita output levels in the context of several other countries such as Czech Republic (Jana and Monika (2012)), Brazil, China, and Bangladesh (Hossain (2000)) and this has interestingly become an active area of research. There have also been some studies on convergence in the context of India, notably Rao *et al.* (1999) and Dasgupta *et al.* (2000). Both the studies found divergence across the states.

It is also important to note that the classical approach to convergence based on cross-country regression, as stated above, came under criticism by Quah (1993), Quah (1996), Bernard and Durlauf (1996). Quah (1993) pointed out that the convergence hypothesis must incorporate the time series properties of the cross-country variances. Quah (1994), and Evans and Karras (1996b) developed a formal panel unit root test for evaluating the convergence hypothesis. Thereafter several papers following this approach have been written.

In case of India, some attempts have been made recently to understand the regional pattern of agricultural development in India applying this statistical tool of convergence. For instance, Mukherjee and Kuroda (2003) explored the question of convergence in total factor productivity across fourteen major agricultural states of India covering the period 1973–1993, and found no evidence of sigma convergence. On the other hand, Somasekharan *et al.* (2011) tested the convergence hypothesis in per capita agricultural output and foodgrains productivity across the fifteen major states of India during 1971–2007 and found that both sigma and beta convergence do not hold.

These studies have mainly focused on convergence of productivity and agricultural output by using the conventional econometric tools. However, as food and nutrition have now become important issues in developmental perspective, it is pertinent and useful to analyze the cross-regional (state) variations in foodgrains availability in a country like India which is now considered to be an important emerging economy. In its report in 2009, the National Centre for Agricultural Economics and Policy Research has stated that despite shift in dietary pattern against cereals, foodgrains is still considered to have paramount importance for household food and nutritional security for low income masses in India. Further, in a country specific study on India, Chand and Kumar (2006) have reported that as yet foodgrains are the major and the cheapest sources of energy and protein compared to other foods.

Considering the availability of foodgrains per capita as a conventional measure of food security and its importance in addressing the three important developmental issues *viz.*, nutrition, hunger and extreme poverty, this paper aims at studying the convergence in foodgrains production across the major foodgrains producing states of India covering the period 1991–92 to 2011–12 by applying the modern methodologies for convergence hypothesis based on panel data such as panel unit root test, static panel and dynamic panel regressions. This apart, the conventional testing procedures for sigma convergence based on standard deviation, coefficient of variation and the Theil's regional inequality index have also been carried out.

In this context it is relevant to point out that there is a difference between foodgrains production and foodgrains availability as foodgrains can be traded from a surplus- producing state to deficit-producing states. In view of this, we have also examined the regional convergence of per capita cereal consumption[3] both at the rural and urban levels across the states taking the time points as 1993–94, 1999–2000, 2004–05 and 2009–10 only since the consumption data, as per the different rounds of the National Sample Survey Organization of India (NSSO) reports, are available at these years only.

Findings based on all these techniques together would enable us to understand the spatial or cross-regional technological spillover in agriculture across Indian states i.e., whether a poor state has shown tendency to catch up with rich ones in terms of levels of per capita foodgrains production and cereal consumption, which thus ensures the food security at the state level. The overall finding based on the panel unit root tests, panel regression model and dynamic panel model is that beta convergence has been achieved in foodgrains production across the major foodgrains producing states of India.

The evidence of beta convergence with per capita cereal consumption is mixed. Whereas the panel unit root and panel regression results confirm the beta convergence for rural consumption, only panel unit root test results infer the same in case of urban consumption. The dynamic panel results do not show any evidence of this convergence for per capita cereal consumption data. The conventional approach of sigma convergence, however, does not show any convergence either in per capita production or consumption.

The paper is organized as follows. The next section describes the methodology. The details on data are stated in Section 3. Section 4 discusses empirical analysis. The paper ends with some concluding remarks in Section 5.

2. METHODOLOGY

In this section, we discuss briefly the different approaches used to study convergence in terms of log of per capita availability (output) of foodgrains per year across the states of India. We first describe the procedure of testing for absolute convergence.

2.1. *Test for absolute convergence*

The well-known concept in case of absolute convergence is sigma convergence. This convergence (divergence) is said to exist if the dispersion of logarithmic values of per capita foodgrains availability across the states follows a downward (upward) trend. Usually standard deviation (σ) and coefficient of variation (η) are used as measures of dispersion. Assuming x_{it} to denote the production of foodgrains of state i in year t, and p_{it} the size of population of state i in year t, the per capita foodgrains production is defined as

$$Y_{it} = x_{it}/p_{it}\,, \quad i = 1, 2, \ldots, n\,; \quad t = 1, 2, \ldots, T\,.$$

The standard deviation and coefficient of variation (CV) of y_{it} values for year t are defined as

[3] Foodgrains consumption data are not available at the state level. However, cereal consumption had more than 80% share in foodgrains consumption in India in the year 2009–10 and even higher in the earlier years. The share of pulse production in total foodgrains was 7.45% at all-India level in 2010–11.

$$\sigma_t = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_{it} - \bar{y}_t)^2} \quad \text{and} \quad \eta_t = \frac{\sigma_t}{\bar{y}_t}, \quad \text{respectively},$$

where $y_{it} = \ln(Y_{it})$, n is the number of states and $\bar{y}_t$ is the mean of y_{it} over the states at time t.

The Theil regional inequality index[4](E_I) which measures regional inequality in per capita foodgrains production across the states, is defined as

$$E_{It} = \sum_{i=1}^{n} s_{it} \log(s_{it}/w_{it})$$

where $s_{it} = x_{it}/\bar{x}_i$ is the relative share in foodgrains of i-th state in t-th year, $\bar{x}_t$ is the all-India (total) foodgrains production in t-th year, n is the number of states and $w_{it} = p_{it}/P_t$ is the population share of i-th state in t-th year, and P_t is the total population of all the n states in t-th year.

The econometric models considered for testing for sigma convergence are the following.

$$\sigma_t = a_0 + a_1 t + e_{1t} \tag{2.1}$$

$$\eta_t = b_0 + b_1 t + e_{2t} \tag{2.2}$$

$$E_{It} = c_0 + c_1 t + e_{3t} \tag{2.3}$$

where e_{1t}, e_{2t} and e_{3t} are assumed to be white noise with zero mean and variances σ_1^2, σ_2^2 and σ_3^2, respectively. In the above models, the null hypothesis (H_o) of 'no sigma convergence' refers to $a_1 = 0$, $b_1 = 0$ and $c_1 = 0$, for models in (2.1), (2.2) and (2.3), respectively, while significant negative (positive) values of these coefficients denote absolute convergence (divergence) for the respective models under the alternative hypothesis. It is worthwhile to note that one major limitation of sigma convergence is that this formulation does not include any dynamical consideration.

2.2. *Convergence hypothesis and panel unit root tests*

The beta convergence is the primary focus of empirical growth literature. It is also a necessary condition for sigma convergence although not sufficient (Young *et al.* (2004)). In several recent studies, panel unit root tests have been used for understanding beta convergence in lieu of cross-section methodology as the latter compromises on the time series properties of the cross-section variances (see, in this context, Quah (1994), Evans and Karras (1996b), and Das and Bhattacharya (2008)). Considering $\tilde{y}_{it} = y_{it} - \bar{y}_t$ as the deviation of y_{it} from cross-state average of log per capita foodgrains production in year t, i.e., $\bar{y}_t = 1/n\sum_{i=1}^{n} y_{it}$, the convergence hypothesis implies the following (see for details, Evans and Karras (1996b)):

$$\underset{j\to\propto}{Lt}\; E_t(\tilde{y}_{i,t+j}) = \mu_i \,.$$

[4] The Theil regional inequality index satisfies several desirable properties, namely, additive decomposability, mean independence, the principle of population replication and the Pigou-Dalton principle of transfer.

Here μ_i is the state-specific parameter determining the level of i-th state's parallel growth path. The above condition holds if and only if $\{\tilde{y}_{it}\}$ is stationary. Now, in case μ_i is zero, the convergence will be stated to be absolute.

The relevant dynamic process for convergence is

$$\Delta \tilde{y}_{it} = \mu_i + \rho \tilde{y}_{i,t-1} + \varepsilon_{it}\,, \quad i = 1, 2, \ldots, n\,; \quad t = 1, 2, \ldots, T \tag{2.4}$$

where $\varepsilon_{it} \sim iid(0, \sigma^2)$.

The null hypothesis for panel unit roots is $H_0 : \rho = 0$ while the alternative is $H_1 : \rho < 0$. Now, if the null hypothesis is rejected then the series $\tilde{y}_{it}$ is stationary i.e., $\tilde{y}_{it}$ is mean reverting implying that the deviation of the series of (log) per capita foodgrains production in each state (i.e., y_{it}) from the cross-state average (i.e., $\bar{y}_t$) is temporary. Thus a negative significant value of the test statistic under the null of $\rho = 0$ implies beta convergence.

Although Quah (1994) first developed the panel unit root test for convergence, this test could not be extended to the case where individual and time specific effects are incorporated (see, in this context, Maddala and Kim (1998)). We now consider the exhaustive panel unit root test as suggested by Levin *et al.* (2002), hereafter referred to as the LLC test, where the following augmented Dickey-Fuller (ADF) version of the model is considered.

$$\Delta \tilde{y}_{it} = \mu_i + \rho \tilde{y}_{i,t-1} + \sum_{j=1}^{m} \delta_j \Delta \tilde{y}_{i,t-j} + \varepsilon_{it}\,, \tag{2.5}$$

where $\varepsilon_{it} \sim iid(0, \sigma^2)$. The null hypothesis is, as before $H_0 : \rho = 0$.

There is another test due to Im *et al.* (2003), called the IPS test, which relaxes the assumption of constancy of ρ for all cross section units under the alternative hypothesis assumed by the LLC test. Thus, in this case, panel unit root test is conducted for individual cross section units, which is in contrast to the LLC test which assumes a common unit root process for the pooling data.[5] For determining the lag order m, the usual model selection criteria like the AIC and BIC are used.

Finally, Maddala and Wu (1999) proposed another test which is originally due to Fisher[6] in the context of panel unit root. It may be noted that Maddala and Wu (1999) compared the powers of the LLC, IPS and the Fisher tests, and found that in a variety of situations Fisher test is more powerful than the IPS and LLC tests.

There is a growing literature which suggests that the conventional assumption of cross- sectional independence of disturbances for these panel unit root tests may not be appropriate (see, in this context, Pesaran (2004), Baltagi (2005), and Breitung and Das (2005)). To this end, Pesaran (2004) performed a simple modified Lagrange Multiplier (MLM) test for testing the cross-sectional dependence. It is, however, worth noting that Levin *et al.* (2002) argued that the demeaned series satisfies this cross-sectional

[5] The implicit assumption for the IPS test is that T is the same for all the cross section units i.e., the panel data is a balanced one.

[6] Fisher (1932) suggested this testing procedure for combining the evidence from several independent tests.

independence. Accordingly, in this paper we have also considered the demeaned series of panel unit root test. Finally, the panel unit root test proposed by Breitung and Das (2005), called the BD test, which is robust to cross-sectional dependence, has also been performed.

2.3. Convergence hypothesis and panel regression approach

In the context of growth of an economy, beta convergence was first studied by Baumol (1986) and he found an inverse relationship between per capita growth in output and the initial level of log of per capita output. This hypothesis implies that the poorer economies grow faster with lower initial levels of per capita income than the richer ones having higher initial levels of income. The standard procedure for testing beta convergence essentially requires carrying out the following regression

$$\ln\left(\frac{Y_{it}}{Y_{i0}}\right) = \alpha + \beta \ln Y_{i0} + \varepsilon_{it} \tag{2.6}$$

and then testing if β is significant with a negative value.

But in view of the limitation of this procedure, as briefly mentioned at the beginning of this section, and with the availability of panel data, a further development has occurred in terms of adoption of panel data methodology in the regression framework. Since the work of Islam (1995) convergence hypothesis has been extensively studied using panel data models. This involves the following panel regression framework

$$\frac{1}{\tau}\ln\left(\frac{Y_{it}}{Y_{i,t-\tau}}\right) = \mu_i + \beta \ln Y_{i,t-\tau} + \varepsilon_{it}\,, \tag{2.7}$$

where $\varepsilon_{it} \sim iid(0, \sigma^2)$, $Y_{i,t-\tau}$ is the initial per capita foodgrains output of the corresponding state in an initial period $t - \tau$. In this model μ_i is the state-specific fixed effect to control for unobserved time-invariant heterogeneity. The significant negative (positive) value of β implies beta convergence (divergence) in per capita foodgrains production.

In this procedure, several choices of the value of τ is made, and panel least squares method is applied. The implied speed of convergence,[7] λ, is obtained as $\lambda = -\frac{1}{\tau}\ln(1 - \beta)$, and the half line of convergence which is defined as the time that it takes for half the initial gap between the own steady state per capita output and the actual per capita output, is nothing but $t_{1/2} = -\frac{\ln(2)}{\lambda}$ Finally, it may be noted that the heteroscedasticity (consistent) covariance matrix estimator of White (1980) has been used to compute the standard errors of the estimates involved as the usual OLS standard error formula is not appropriate here.

2.4. Convergence hypothesis and dynamic panel models

The static panel has two basic problems. First, it does not take into account the proper dynamics of the model and second, it cannot take care of the endogeneity between $y_{i,t-\tau}$ and μ_i. Since the unobserved panel-level effects are correlated with the

[7] λ is calculated from the β coefficient of the panel regression equation given in (2.7). Note that $\beta = \frac{(1-e^{-\lambda\tau})}{\tau}$, and it approaches 0 as τ goes to infinity, and λ as τ goes to 0.

lagged dependent variables, the standard estimators become inconsistent. However, Arellano and Bond (1991) derived consistent estimators for the dynamic panel model based on generalized method of moments (GMM) of the first differenced values. But as the GMM estimator based on first difference suffers from the problem of weak correlations between growth rate of per capita output and the lagged (log) per capita output level, which is referred to as the weak instrument problem, the system GMM estimator has been subsequently developed by Bond and Blundell (1998), which represents a significant improvement over the former. In this procedure, obviously $\tau = 1$ and the model stated in equation (2.7), reduces to

$$\ln Y_{it} - \ln Y_{i,t-1} = \mu_i + \beta \ln Y_{i,t-1} + v_{it} ,$$

which can be written as

$$\ln Y_{it} = \mu_i + b \ln Y_{i,t-1} + v_{it} \tag{2.8}$$

where $b = 1 + \beta$.

Thus finally, the GMM first differenced (GMM-FD) estimator involves the following form

$$\Delta \ln Y_{it} = b \Delta \ln Y_{i,t-1} + \Delta v_{it} , \tag{2.9}$$

while this equation along with the one with level values i.e., equation (2.8), constitute the system GMM (GMM SYS).

Assuming that

$$E(v_{it} v_{is}) = 0 \quad \text{for } i = 1, 2, \ldots, n ; \quad t \neq s ,$$

we exploit the moment conditions

$$E(Y_{i,t-s} v_{is}) = 0 \quad \text{for } t = 3, 4, \ldots, T \text{ and } s \geq 2 .$$

For both the cases, the beta convergence hypothesis hold when $b < 1$.

In case of the same kind of analysis with foodgrains consumption data, we assume R_{it} and U_{it} to denote the rural and urban average monthly per capita cereal consumptions, respectively, in kilograms, of the i-th state in t-th year, and then take their logarithmic transformation i.e., $r_{it} = \ln(R_{it})$ and $u_{it} = \ln(U_{it})$. Again, $\tilde{r}_{it}$ and $\tilde{u}_{it}$ are defined as the mean deviation from the corresponding cross state average, similar to that for $\tilde{y}_{it}$. We follow the same estimation procedure with $\tilde{r}_{it}$ and $\tilde{u}_{it}$ as we did for $\tilde{y}_{it}$ in case of convergence involving panel unit root.

3. DATA

This study covers 15 major foodgrains producing states of India, namely, Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal. The undivided Bihar, Madhya Pradesh and Uttar Pradesh are considered in this study.[8] As

[8] The new states of Jharkhand, Chattisgarh and Uttaranchal were carved out of Bihar, Madhya Pradesh and Uttar Pradesh, respectively, in 2000. For our study, however, we have continued to take the original states even after formation of the new states. Consequently, the data have been obtained by adding figures accordingly for these three states.

availability of foodgrains per capita in India mainly depends on net production of foodgrains[9] we have used foodgrains production per capita for our analysis. For this study, we decided on a minimum share of 1% in all-India foodgrains production for any state to be included. Accordingly, the afore-mentioned 15 states were found to satisfy this criterion. The time period covered is 1991–92 to 2011–12.

The data on state-wise annual foodgrains production for the period 1991–2011 have been collected from 'Data Base for the Indian Economy (DBIE)' published by the Reserve Bank of India (www.rbi.org). And the data on state-wise population for the period 1991 to 2000 have been obtained from the projected population figures, as released by the Standing Committee of the Registrar General of India. The population figures for the period 2001 to 2011 have been taken from the population projections of Census of India, 2001, under the office of the Registrar General of India, Ministry of Home, Government of India. The data on rural and urban average monthly per capita cereal consumption (in kilogram) have been taken from the 66$^{\text{th}}$ round NSSO report conducted during July 2009–June 2010 on Household Consumption Expenditure in India (Report No. 538). These consumption data are available for the years 1993–94, 1999–2000, 2004–05 and 2009–10 only.

All computational works have been done by EVIEWS 7 and STATA 12.

4. EMPIRICAL ANALYSIS

Food is the most important item in terms of basic human needs. Hence, considering the primary importance of foodgrains production in any state, we have first compared the shares of foodgrains of the 15 major states of India with their corresponding population shares at the all-India level. These figures are presented in Table 1. We find from this table that over the period 2002 to 2011, average shares of foodgrains have exceeded the corresponding population shares in 2011 for the states of Punjab, Haryana, Uttar Pradesh, Rajasthan and MP. However, for states like Assam, Bihar, Gujarat, Kerala, Maharashtra and Tamil Nadu, population shares are much higher than the shares of foodgrains production. For the remaining states *viz.*, for Andhra Pradesh, Karnataka, Orissa and West Bengal, these two shares are very close.

Now, insofar as growth performance is concerned, apart from the high performing states, some of the poorly and moderately performing states like Karnataka, Gujarat, West Bengal and Bihar have (average) annual growth rates of more than 2% during the period 1981–2011. It is also seen that states like Maharashtra, Orissa and Kerala have been performing very poorly in terms of (average) annual growth with the figures being 0.75%, 0.24% and −2.71%, respectively during the same period. However, it may be interesting to note that during the period covering 2002 to 2011, (average) annual growth rate of each of Punjab and Uttar Pradesh is around 1.30%, while that of West

[9] Two other items of information required for obtaining foodgrains availability per capita are net imports and change in Government stocks, and these two figures are positive in India since early 1990. Further, the state-wise import data are not available. Hence, these two could not be used for the purpose of obtaining the figures for availability of foodgrains. Hence, foodgrains output has been taken to represent foodgrains availability.

Table 1. State-wise average share and average growth of foodgrains production and also population share

State	Average (over the period 2002–03 to 2011–12) share (%) in foodgrains production	Average (over the period 1981–82 to 2011–12) growth rate in foodgrains production	Average (over the period 2002–03 to 2011–2012). growth rate in foodgrains production	Population share (%) in 2011
Andhra Pradesh	7.55	1.97	2.15	7.41
Assam	1.80	1.41	0.41	2.59
Bihar	6.32	2.05	2.96	11.60
Gujarat	2.99	2.28	6.14	4.99
Haryana	6.77	3.51	3.00	2.09
Karnataka	4.88	2.35	3.38	5.05
Kerala	0.29	−2.71	−2.51	2.76
Madhya Pradesh	9.13	2.37	2.89	8
Maharashtra	5.69	0.75	0.96	9.29
Orissa	3.19	0.24	−1.62	3.47
Punjab	12.10	2.80	1.30	2.29
Rajasthan	6.60	3.46	3.03	5.67
Tamil Nadu	3.16	1.82	2.21	5.96
Uttar Pradesh	20.75	2.38	1.29	17.33
West Bengal	7.33	2.18	−0.13	7.55

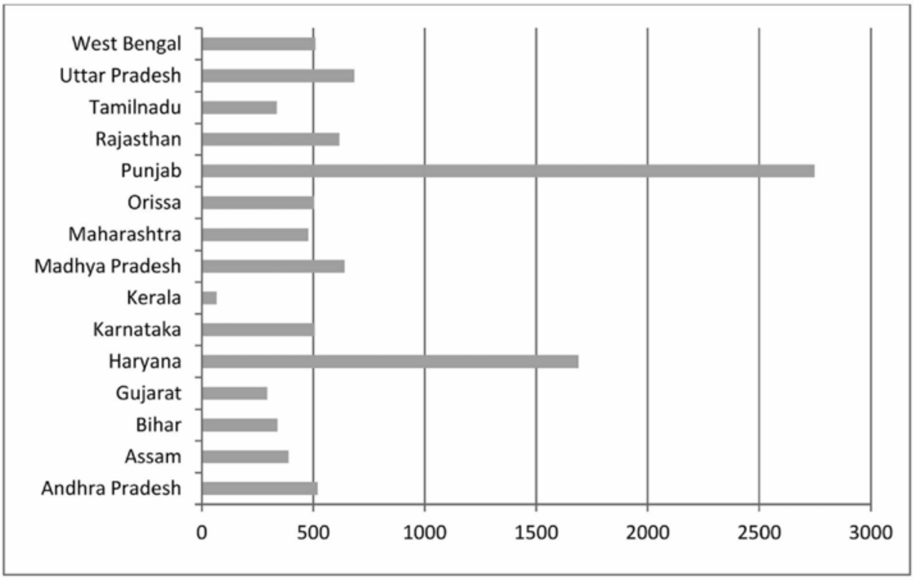
NOTE: The entries in the fifth column are based on 2011 Census figures. Growth rate is the simple average of annual growth rates where the annual growth rate is defined as the first logarithmic (natural) difference in foodgrains production in thousand tonnes.

Bengal is close to zero (−0.13%). However, Orissa is found to have a negative growth of −1.62% during the same period.

In order to get a pictorial representation of the extent of differences in foodgrains production per head per day across the states, we have plotted these figures as averages over the period 1991–92 to 2011–12 in a horizontal bar diagram in Figure 1. It is quite obvious from Figure 1 that Punjab is way above the mark with the highest (average) over the period 1991–92 to 2011–12 per day per capita availability of foodgrains of 2747.72 grams, and it is followed by Haryana with the figure of 1688 grams. On the other hand, the two most poorly performing states are Kerala and Gujarat with the figures being 66.78 grams and 292.12 grams, respectively.

4.1. *Findings on sigma convergence*

We first report our findings on sigma convergence. The estimated equations (*cf.* equations (2.1), (2.2) and (2.3) in Section 2) with the three measures of dispersion/inequality *viz.*, standard deviation (σ_t), coefficient of variation (η_t) and the Theil's regional inequality index (E_{It}) as the regressands respectively, and 't' as the regressor in all the three, are given below.



Note: The average is computed based on yearly figures covering the period from 1991–92 to 2011–12.

Figure 1. State-wise distribution of foodgrains production per day per capita in gram.

$$\hat{\sigma}_t = 0.726 + 0.009t;\ Adj.R^2 = 0.621 \quad (4.1)$$
$$(39.002)^*(5.816)^*$$

$$\hat{\eta}_t = 0.139 + 0.002t;\ Adj.R^2 = 0.652 \quad (4.2)$$
$$(38.576)^*(6.201)^*$$

$$\hat{E}_{It} = 0.058 + 0.001t;\ Adj.R^2 = 0.408 \quad (4.3)$$
$$(13.682)^*(3.842)^*$$

(*Notes: The figures in parentheses indicate t-statistic values. * indicate 1% level of significance.*)

All the three estimated equations show that the coefficients of trend are positive and significant at 1% level of significance. The conclusion, therefore, is that the per capita foodgrains production show significant sigma divergence across the Indian states. The diagrams in Figures 2 to 4 showing the plots of each of these measures of dispersion against time also show upward movements of these measures over time, although not so distinct in case of the third measure. Further, it may also be noted that the value of standard deviation has increased from 0.731 in 1991 to 0.878 in 2011 implying that the regional inequality across the states in per capita foodgrains production has increased during this period. The same conclusion holds in terms of coefficient of variation and the Theil's regional inequality index.

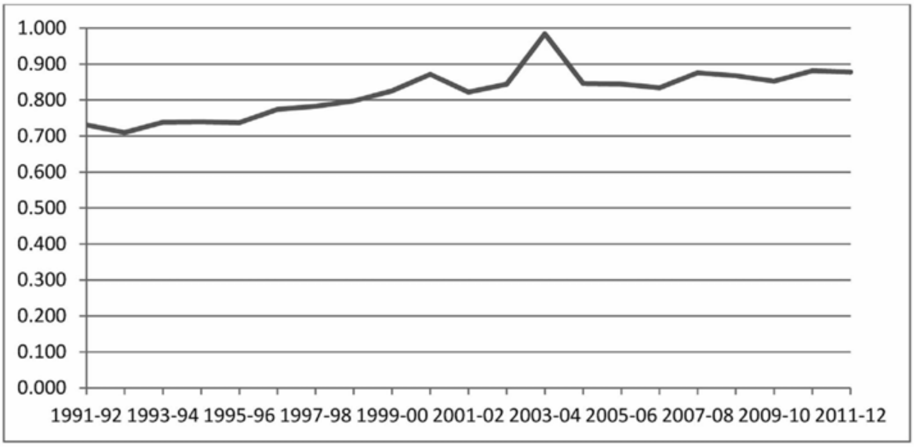


Figure 2. Sigma convergence based on standard deviation.

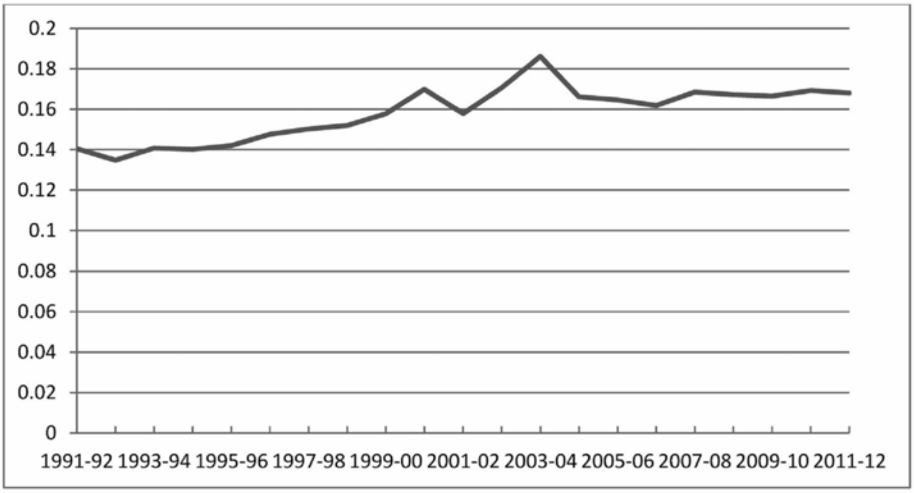


Figure 3. Sigma convergence based on coefficient of variation.

The evidence of sigma convergence is not found in case of per capita cereal consumption both for the rural and urban areas as well. The value of standard deviation for the rural cereal consumption has fallen from 0.133 in 1993–94 to 0.119 in 2004–05 but again risen to 0.121 in 2009–10, implying that the regional inequality in rural consumption has not declined smoothly during this period. The standard deviation for the urban per capita cereal consumption, however, has risen from 0.118 in 1993–94 to 0.124 in 2009–10. The coefficient variation (CV) figures show similar observations both for rural and urban areas. These results are presented in Table 2.

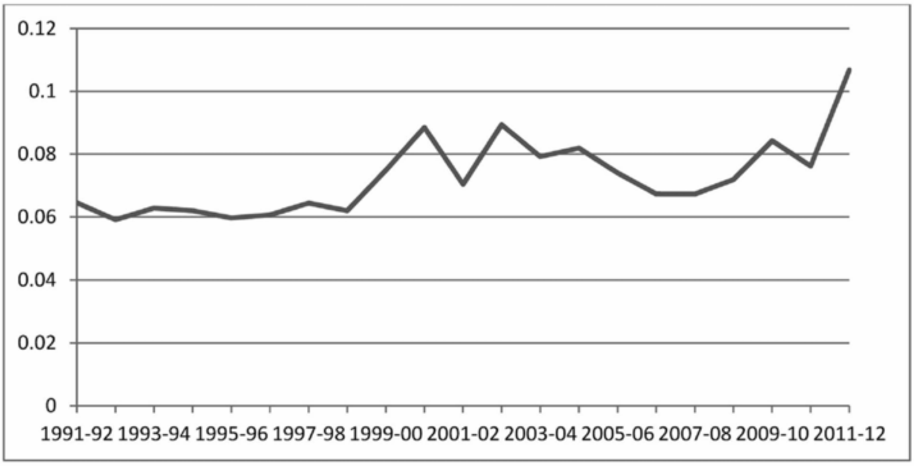


Figure 4. Sigma convergence based on the Theil's regional inequality index.

Table 2. Sigma convergence for per capita rural and urban cereal consumptions

	Rural		Urban	
Year	Standard deviation	CV	Standard deviation	CV
1993–94	0.133	0.052	0.118	0.050
1999–00	0.127	0.051	0.133	0.056
2004–05	0.119	0.049	0.126	0.054
2009–10	0.121	0.051	0.125	0.055

4.2. Results of panel unit root tests (beta convergence)

The test statistic values of all the panel unit root tests are presented in Table 3. It is quite obvious from the LLC test results that the demeaned series, $\tilde{y}_{it}$, is stationary since the LLC adjusted test statistic value of -8.633 rejects the null of panel unit root at 1% level of significance. Since the significant coefficient is negative in sign, it implies beta convergence[10] for the series of (logarithm) of per capita production of foodgrains of all the major Indian foodgrains producing states to the all-India average. Incidentally, this study thus turns out to be one where beta convergence holds but not sigma convergence, giving credence to the result that beta convergence is necessary but not sufficient for sigma convergence.

Exactly the same conclusion on the stationarity of the demeaned series has been obtained by the IPS test also at 1% level of significance. The IPS test statistic has been found to be -7.424, which is significant at 1% level of significance, thus clearly confirming the beta convergence of the series. We have also carried out the Fisher test and obtained the same conclusion. This test has two variants. The ADF-Fisher χ^2 and the

[10] This convergence can be considered as conditional instead of absolute or unconditional (sigma) since non-zero intercept has been allowed in the ADF equation.

Table 3. Results of panel unit root tests

Per capita foodgrains production: demeaned series ($\tilde{y}_{it}$)		
Test	Statistic value	p-value
LLC	−8.633	0.000
IPS	−7.424	0.000
ADF–Fisher Chi-square	70.688	0.000
PP-Fisher Chi-square	158.871	0.000
BD	−3.202	0.000
Rural per capita cereal consumption: demeaned series ($\tilde{r}_{it}$)		
LLC	25.724	0.000
ADF–Fisher Chi-square	55.167	0.003
PP-Fisher Chi-square	73.418	0.000
Urban per capita cereal consumption: demeaned series ($\tilde{u}_{it}$)		
LLC	59	0.000
ADF–Fisher Chi-square	60.03	0.000
PP-Fisher Chi-square	70.718	0.000

NOTE: The panel unit root tests have been carried out using the methodology as described in Section 2. In all the tests, panel means have been included but not the time trend. The panel on $\tilde{y}_{it}$ consists of 15 cross section units (i.e., states) and 21 time points and the panel on $\tilde{r}_{it}$ and $\tilde{u}_{it}$ consists of 15 cross section units (i.e., states) and 4 time points. Maximum lag value allowed was 5 and the optimal lag was chosen by the Schwarz model selection criterion (BIC). The IPS and the BD tests could not be conducted on $\tilde{r}_{it}$ and $\tilde{u}_{it}$ due to insufficient number of observations.

PP-Fisher χ^2 test statistic values have been obtained as 70.688 and 158.871, respectively. Both these values are significant at 1% level of significance.

At this stage it is worthwhile to note that it is important to know if the assumption of cross sectional independence across the states is empirically valid or not for this panel data. Accordingly, the modified LM test of Pesaran was applied and the test statistic value turned out to be -1.918 which is significant at 10% level implying weak presence of contemporaneous cross sectional dependence. Since the LLC and IPS tests assume that there is no cross-sectional dependence, this finding, although not strong statistically, may raise doubt about the conclusion of beta convergence based on these two tests. Hence, we also conducted the panel unit root test that has been proposed by Breitung and Das (2005). The value of the test statistic is found to be -3.202 and the p-value 0.001. Thus, this test which is robust to cross sectional dependence, strongly rejects the null of panel unit root.

Taking all these test results, we can, therefore, conclude that the assumption of stationarity of the demeaned series $\{\tilde{y}_{it}\}$ holds for this panel data. Hence, we conclude that the hypothesis of beta convergence holds for (log) per capita production of foodgrains across the 15 major Indian states over the period 1991 to 2011.

4.3. *Panel regression-based convergence*

We now present the findings on approaches based on panel regression in Table 4. In this exercise, three initial periods *viz.*, $\tau = 1, 5$ and 10 have been taken. For the fixed

Table 4. Beta convergence in panel regression under fixed effects

Dependent variable: $\ln Y_{it} - \ln Y_{i,t-1}$				
Variable	Coefficient	Standard error	t-statistic	p-value
Constant	4.529	0.590	7.674	0.000
$\ln Y_{i,t-1}$	−0.873	0.114	−7.688	0.000
Implied speed of convergence (λ)	−0.628			
Half line in years	1.105			
Adj. R-square	0.413			
Dependent variable: $(1/5)^*(\ln Y_{it} - \ln Y_{i,t-5})$				
Variable	Coefficient	Standard error	t-statistic	p-value
Constant	1.054	0.067	15.643	0.000
$\ln Y_{i,t-5}$	−0.204	0.013	−15.624	0.000
Implied Speed of convergence (λ)	−0.037			
Half line in years	18.668			
Adj. R-square	0.512			
Dependent variable: $(1/10)^*(\ln Y_{it} - \ln Y_{i,t-10})$				
Variable	Coefficient	Standard error	t-statistic	p-value
Constant	0.476	0.096	4.973	0.000
$\ln Y_{i,t-10}$	−0.092	0.019	−4.982	0.000
Speed of convergence (λ)	−0.018			
Half line in years	39.379			
Adj. R-square	0.367			
Dependent variable: $\ln R_{it} - \ln R_{i,t-1}$				
Variable	Coefficient	Standard error	t-statistic	p-value
Constant	0.346	0.221	1.565	0.128
$\ln R_{i,t-1}$	−0.161	0.088	−1.828	0.078
Implied speed of convergence (λ)	−0.149			
Half line in years	4.643			
Adj. R Square	0.117			
Dependent variable: $\ln U_{it} - \ln U_{i,t-1}$				
Variable	Coefficient	Standard error	t-statistic	p-value
Constant	0.384	0.453	0.847	0.404
$\ln U_{i,t-1}$	−0.179	0.11	0.927	0.362
Implied speed of convergence (λ)	−0.167			
Half line in years	4.209			
Adj. R-square	−0.20			

effects model with $\tau = 1$, the least squares estimate of β has been found to be -0.873 which is highly significant since the underlying test statistic value is -7.688. It is to be noted that the sign of $\hat{\beta}$ is negative. One can thus conclude that the growth rate in per capita production of foodgrains is inversely related to its initial level across the 15 Indian states during the period 1991–92 to 2011–12.

We also find from the panel regression results corresponding to 5 years' past as the initial period that β is -0.204 and the resulting test statistic value is 15.642 which is

Table 5. Estimation results for dynamic panel

Variable	Coefficient	Std. error	Test statistic	p-value
Arellano-Bond dynamic panel data estimation				
$\ln Y_{i,t-1}$	0.094	0.057	1.67	0.096
Constant	4.693	0.294	15.99	0.000
System dynamic panel data estimation				
$\ln Y_{i,t-1}$	0.198	0.04	4.345	0.000
Constant	4.162	0.237	17.58	0.000

obviously highly significant. The conclusions are exactly the same in case of $\tau = 10$. Therefore, the results of panel regression with fixed effects under the various choices of the initial period clearly establish beta convergence in the (log) of initial per capita foodgrains output across Indian states during 1991–92 to 2011–12. Although the panel regression estimate of β for rural per capita cereal consumption is significant at 10% level of significance with the test statistic value being 1.828, the corresponding value for the urban consumption is insignificant, as shown in Table 4.

Finally, the dynamic panel based results are given in Table 5. The first-differenced GMM based results following the Arellano and Bond estimation procedure show that the coefficient attached to the lagged dependent variable being 0.094 is statistically significant at 10 per cent level, and that it is positive and less than 1. This implies that the agriculturally poor states in terms of per capita foodgrains production are growing at a faster rate than their richer counterparts. This significance also demonstrates beta convergence for the time series concerned across the Indian states.

The GMM system based results also show positive and statistically significant coefficient at 1 per cent level. The coefficient estimate is less than 1 in this case as well. The estimated coefficient value is 0.198 which is less than 1, implying prevalence of convergence in per capita production of foodgrains across Indian states over the period 1991 to 2011. Since the system GMM improves the precision and reduces the finite sample bias and thus overcomes many disappointing features of the standard first differenced estimator, therefore the system GMM results should be considered to be more reasonable.

Thus the conclusion that can be drawn is that the time series of per capita foodgrains production across the 15 major foodgrains producing states of India has achieved beta convergence over the period 1991–2001. We conclude this section by stating that we have not found convergence by using the dynamic panel for both rural and urban per capita cereal consumptions from the first differenced GMM as well as the system GMM methods since the estimates were found to be greater than one and statically insignificant by both the methods, and hence these are not reported in Table 5.

5. CONCLUSIONS

In this paper we have studied the pattern of regional convergence in per capita level of foodgrains production across the major foodgrains producing states of India for the period 1991 to 2011 by applying the modern panel data- based methodologies available for convergence hypothesis such as panel unit root tests, panel regression model and dynamic panel models. We have also followed the conventional testing of sigma convergence using the time trend of standard deviation, coefficient variation and the Theil's regional inequality index as measures of dispersion. We have also examined the regional convergence for per capita cereal consumption both at the rural and urban levels across these states taking four time points only for which data are available.

The first finding based on the conventional approach of sigma convergence clearly demonstrates that sigma convergence has not been achieved in levels of (log) per capita production of foodgrains across the Indian states during the period 1991 to 2011. The same is the conclusion also for the per capita cereal consumption both for rural and urban India. Methods based on panel data, on the other hand, clearly establish the significant presence of this convergence in per capita foodgrains production. This implies that each state has converged to its own steady state level.

All the standard panel unit root tests including those robust to cross-sectional dependence, clearly show stationarity in the demeaned series of (log) per capita foodgrains production, implying beta convergence. We have also found, by applying the panel least squares with fixed effects allowing state specific factors, that negative but statistically significant relationship exists between growth (averaged over 1991 to 2011) in per capita foodgrains production and the initial levels.

This shows that the agriculturally poor states are moving at a faster rate compared to the agriculturally rich states, indicating thereby the 'catch up effect' in foodgrains production. This can be termed as spatial spillover of technological progress in modern agriculture. We have also found beta convergence by the first differenced GMM and system GMM methods following dynamic panel framework.

As regards the findings with per capita cereal consumption data, we have found some evidence of beta convergence for rural per capita cereal consumption by some tests based on panel unit root and panel regression, but no such evidence has been found for urban per capita cereal consumption. This result can be explained in terms of the widening regional inequality in urban economic growth.

Thus, based on a number of modern as well as conventional statistical tests, beta convergence in per capita foodgrains production across the Indian states over 1991 to 2011 is a confirmed empirical finding. Since all these tests are based on statistically very sound methodologies as opposed to the conventional sigma convergence, we can conclude very strongly on convergence in foodgrains production across the major foodgrains growing states of India. This finding is quite important from the developmental perspective in India since the issues of food security and nutrition are currently gaining momentum in the domains of public debate and the policy decisions of the government.

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