Ind. Jn. of Agri. Econ.
Vol. 61, No. 4, Oct.-Dec. 2006

Regional Convergence in Indian Agriculture

Madhusudan Ghosh*

I

INTRODUCTION

The issues of regional economic growth and disparity have attracted considerable attention among researchers, planners and policy makers. Since Independence, the Indian government has been concerned about how to strengthen national unity and promote economic growth with regional equity. Balanced growth of all regions of the country has been considered essential for political stability, national integration and economic viability of the nation itself. Naturally, the issue of regional balance has been given sharp focus in all the plans, and various policies and programmes have been adopted for achieving high economic growth and fostering regional balance with the primary objective of achieving all-round development of the economy.

In a predominantly agrarian economy like India where a substantial amount of gross domestic product (GDP) comes from agriculture and a large proportion of the population depends on it, achievement of these objectives depends largely on the performance of the agricultural sector. With a view to accelerating agricultural growth, India has undertaken land reform measures and large investment programmes in irrigation, power, roads and other rural infrastructure. The introduction of new high-yielding variety (HYV) technology in the mid-1960s was instrumental in bringing about unprecedented growth in the output and yield of major cereal crops like wheat and rice. The adoption of new technology has ushered in an era of Green Revolution (GR) in agriculture, and agriculture in several parts of the country has undergone significant transformation.

Indian agriculture is, however, characterised by large inter-regional disparities. The disparities in agricultural development have often been attributed to inter-regional variations in agro-climatic conditions and resource endowment (viz., availability of irrigation and other rural infrastructure). Being highly irrigation

*Professor of Economics, Department of Economics and Politics, Visva-Bharati, Santiniketan – 731 235, Birbhum (West Bengal).

The author is thankful to the anonymous referee of the Journal for constructive comments and suggestions on an earlier version of the paper. However, the author alone is responsible for any remaining errors. The paper forms a part of the author’s major research project “Economic Reforms and Regional Convergence in Indian Agriculture”, sponsored by the University Grants Commission (UGC), New Delhi. Financial support from UGC is gratefully acknowledged.

intensive, the new technology was initially adopted on a large scale in the irrigated areas of Punjab, Haryana and western Uttar Pradesh, which recorded significant acceleration in crop output. This resulted in accentuating the existing disparities in the levels and growth of agricultural output across various regions. However, the new technology was gradually disseminated to several other regions. This led to significant acceleration in the growth rate of agricultural output in those regions. This phenomenon is expected to bring about a reduction in the extent of regional disparities in agricultural output and productivity.

The Indian government has been implementing comprehensive economic reforms involving large-scale structural adjustment and liberalisation programmes since 1991. The policies that have direct and indirect bearing on agriculture are expected to bring about changes in the agricultural sector. The on-going economic reforms and gradual opening up of Indian agriculture to world economy through the liberalisation of both domestic and external trade are expected to provide incentives for regional specialisation in crops according to comparative advantage. The consequent changes in cropping pattern are expected to produce significant effects on the spatial pattern of agricultural development. The dynamics of change in the regional disparities of agricultural development would depend on the nature of regional distribution of gains from the economic reforms. Against this background, it seems important to examine the direction of change in the regional disparities of agricultural development due to the economic reforms and dissemination of new agricultural technology in India.

There are few studies that examine the nature of regional disparities in agricultural development (see, for example, Bhalla and Singh, 1997, 2001; Bhalla and Tyagi, 1989; Dev, 1985, 1986, 1987; Rao, 1980; Bhalla and Alagh, 1979; Krishnaji, 1975). The general observation is that the degree of regional disparity in agricultural development has been very high. However, there exists no comprehensive study examining the issue of convergence or divergence in agricultural development across different regions in India, using the recently developed convergence techniques. Some studies (for example, Trivedi, 2002; Sachs *et al.*,2002; Dasgupta *et al*., 2000; Rao *et al*., 1999; Nagaraj *et al*., 1998; Ghosh *et al*., 1998; Cashin and Sahay, 1996a,b; Marjit and Mitra, 1996) have examined regional convergence in real per capita income (i.e., real per capita state domestic product) across major states of India. While some of them have provided evidence in favour of the convergence hypothesis, others have found evidence, which indicates that per capita incomes in the Indian states have tended to diverge rather than converge over time.

Since the contribution of the agricultural sector to GDP is large in a developing country like India, it has often been argued that regional disparities in per capita income has been largely due to regional variations in agricultural development. For example, Das and Barua (1996) have argued that regional variations in agriculture and infrastructure are the largest sources of inequality among various regions of the country, and regional inequalities in agriculture have been persisting. Examining the regional convergence of total factor productivity (TFP) in agriculture across 14 major states of India during 1973-93, Mukherjee and Kuroda (2003) have found evidence in favour of conditional β-convergence after controlling for state-specific factors, but no evidence to support convergence to a single TFP level (σ-convergence).

Our estimates of correlation coefficient reveal that inter-state disparities in per capita state domestic product (SDP) are positively correlated with those in per capita agricultural output. The correlation coefficient between the coefficient of variation (CV) of per capita agricultural output and that of per capita SDP turns out to be 0.892, and the correlation coefficient between the standard deviations (SD) of the two variables turns out to be 0.841 during 1960-2002. Since agriculture is the predominant sector in all the major states, the overall economic development of the states depends largely on agricultural development. It has been observed that agricultural performance has significant influence on inequality and poverty in the rural areas. Therefore, from the point of view of balanced regional development in the economy in general, and in agriculture in particular, it is important to understand the long-run movement of regional disparities in agricultural output and productivity, and to respond appropriately to correct such imbalances. Since the regional disparities in agricultural development appear to be one of the major sources of persisting regional disparities in per capita income in the country, and the regional inequality in agricultural development has profound significance for the regional disparities in the standard of living of the rural people, it is important to examine the convergence hypotheses for the agricultural sector separately, with special focus on the question of whether there has been a tendency towards convergence or divergence in agricultural output and productivity across regions.

II

OBJECTIVE AND DATABASE

Using the methodology suggested by Barro and Sala-i-Martin (1992, 1995) and Sala-i-Martin (1996), this paper examines regional convergence in agricultural development across 15 major agricultural states in India during 1960/61-2001/02 (see Table 1 A for names of the states). It specifically investigates whether there exists convergence (σ-convergence, and absolute – and conditional-β convergence) in land and labour productivity and per capita agricultural output across the states, particularly after the dissemination of new HYV-technology and the implementation of large-scale economic reforms. It also accounts for the regional convergence or divergence in land and labour productivity and per capita agricultural output with special emphasis on the role of land area, rural infrastructure, and physical and human capital. Moreover, applying the univariate non-stationary time-series method suggested by Phillips (1987) and Phillips and Perron (1988), we attempt to identify the states, which are converging to or diverging from the national average steady-state level of agricultural output. The study is based on the data compiled from Government of India (2004), Bhalla and Singh (2001), EPW Research Foundation

(1998), Chandhok and the Policy Group (1990), Bhalla and Tyagi (1989), and Registrar General and Census Commissioner (1971, 1981, 1992, 2004).

III

MEASURES OF CONVERGENCE

An important result that follows from the standard neoclassical growth model (Solow, 1956; Swan, 1956) is the convergence of per capita output across countries with a similar population growth rate, educational attainment, saving, investment and depreciation rates, and productivity growth. Based fundamentally on the assumption of diminishing returns to capital, the convergence hypothesis says that the growth rate in the country with lower per capita output should be higher than in the country with higher per capita output. When this happens, then the inter-country differences in per capita output will disappear over time. Barro (1997) describes the economic notion of convergence in the following way:

> *"The convergence property derives in the neoclassical model from the diminishing returns to capital. Economies that have less relative capital per worker (relative to their long run capital per worker) tend to have higher rates of return and higher growth rates."*

Barro (1991), Barro and Sala-i-Martin (1992, 1995), and Sala-i-Martin (1996) have converted the economic notion of convergence into a well-defined statistical hypothesis. Three concepts of convergence are distinguished in the literature: (a) σ-convergence, (b) absolute or unconditional β- convergence, and (c) conditional β-convergence. Empirical convergence analyses are based primarily on cross-sectional growth regressions.

The concept of σ-convergence concerns with cross-sectional dispersion of per capita income. σ-convergence is said to exist if the dispersion of per capita incomes across regions decreases over time. It focuses on the evolution of cross-sectional distribution of income over time. The existence of σ-convergence implies a tendency of per capita income to be equal across regions over time.

Whether the presence of σ-convergence in per capita income is due to higher growth rates of the poorer regions than the richer ones can be examined by looking into the presence of β-convergence. Absolute β-convergence is said to exist if the poorer regions tend to grow faster than the richer ones. The existence of absolute β-convergence is empirically examined by estimating cross-sectional regression of annual average growth rate of per capita income on the initial level of per capita income. Thus, testing for absolute β-convergence involves estimation of the following regression equation.

$$G_{i,t,t-\tau} = [\ln(Y_{i,t}) - \ln(Y_{i,t-\tau})] / \tau = \alpha + \beta\ln(Y_{i,t-\tau}) + \varepsilon_{i,t} \qquad \text{.... (1)}$$

where $G_{i,t,t-\tau} = [\ln(Y_{i,t}) - \ln(Y_{i,t-\tau})] / \tau$ is the i-th region's average growth rate of per capita income between the period t and t-τ, and $\ln(Y_{i,t})$ and $\ln(Y_{i,t-\tau})$ are the natural logarithms of the i-th region's per capita income at time t and t-τ respectively. τ is the length of the time period. If the regression coefficient on initial level of per capita income bears a statistically significant negative sign, i.e., if $\beta<0$, then we say that there exists absolute β-convergence. The negative coefficient on initial level of per capita income signifies that the regions with lower initial level of per capita income grow faster than the regions with higher initial per capita income. The existence of β-convergence is a necessary condition for the existence of σ-convergence. It is natural that when an initially poor region grows faster than a rich one, then the levels of per capita income of the two regions will tend to be equal over time. Thus, β-convergence will tend to generate σ-convergence. The existence of β-convergence is a necessary but not a sufficient condition for the existence of σ-convergence. For, whereas σ-convergence concerns with the question of whether or not the dispersion of cross-sectional distribution of income decreases over time, β-convergence concerns with the question of mobility of different regions within the given distribution of income (Sala-i-Martin, 1996).

Absolute β-convergence and the prediction that initially poor regions will grow faster than the rich ones depend on the key assumption that the regions differ in their levels of capital only. In reality, however, regions may differ in many other respects such as level of technology, rate of investment, propensity to save, rate of capital depreciation, population growth rate, literacy rate, etc. These differences may generate different steady states for different regions. In such a condition, absolute β-convergence holds if all regions converge to the same steady state. However, with different steady states for different regions, one has to test for conditional β-convergence, holding the steady state of each region constant. Conditional β-convergence is perceptible only after other factors, which may cause variation in steady states across regions, are accounted for. One way to do this is to include in regression equation (1) those variables that account for variation in steady states across regions. Thus, testing for the hypothesis of conditional β-convergence involves estimation of the following equation:

$$G_{i,t,t-\tau} = [\ln(Y_{i,t}) - \ln(Y_{i,t-\tau})] / \tau = \alpha_i + \beta\ln(Y_{i,t-\tau}) + \sum_{j=1}^{k}\theta_j \ln(X^j_{i,t-\tau}) + \varepsilon_{i,t} \qquad \text{.... (2)}$$

The equation allows us to control for the variables, which might influence the steady-state level of income. The choice of the control variables X^j depends on economic theory, a priori beliefs about growth process, and availability of data. Conditional β-convergence holds if $\beta<0$.

IV

CONVERGENCE IN AGRICULTURAL DEVELOPMENT

This section examines the validity of the convergence hypotheses on the basis of growth experience of the Indian states. Applying the method suggested by Barro and Sala-i-Martin (1992, 1995) and Sala-i-Martin (1996), it specifically examines whether there has been any tendency of convergence in some measures of agricultural development across the states during the period under consideration. It also applies the univariate non-stationary time series (unit-root) method proposed by Phillips (1987), and Phillips and Perron (1988) to identify the states, which are converging to or diverging from the national average steady-state path of agricultural development.

IV.1 Spatial Pattern and σ-Convergence

Agricultural development is measured here in terms of three indicators: (a) Per capita agricultural output (i.e., per capita SDP originating from agriculture) at 1980-81 prices (PCIA), (b) average value of output per hectare at 1990-93 prices (average productivity of land), and (c) average value of output per male agricultural worker at 1990-93 prices (average labour productivity). The state-wise data on level and growth rate of average land and labour productivity and per capita agricultural output are reported in Tables 1A, 1B and 1C respectively. It can be seen that at the all-India level, while land and labour productivity grew at the rate of 2.5 per cent and 1.68 per cent per year respectively, PCIA grew at the rate of 0.77 per cent during 1962/65-1999/2002.

Moreover, there has been a wide variation in the levels and growth rates of land and labour productivity and PCIA across the states over the period. Since the new HYV-technology was initially introduced in wheat and rice in the regions with assured irrigation, only a few states were able to derive the benefits of new technology. The uneven nature of spatial spread of new technology led to an increase in inter-state disparities in the average productivity of land during the early phase of the Green Revolution. Kerala has the highest value of average productivity of land because of the prevalence of cash crops (see Bhalla and Singh, 2001, for details). Table 1A reveals that the coefficient of variation (CV) in the level of land productivity has increased from 50.06 per cent in 1962-65 to 51.69 per cent in 1970-73. However, as the new technology gradually permeated to other regions, and its benefits were shared by them, the regional variations in land productivity declined thereafter. The CV in the level of land productivity has declined from 51.69 per cent in 1970-73 to 43.71 per cent in 1980-83 and further to 41.43 per cent in 1992-95. It has increased slightly to 41.69 per cent in 1999-2002. The regional inequality in the growth rate of land productivity declined consistently during 1962/65-1992/95, as its CV has declined from 101.74 per cent in the 1960s to 89.87 per cent in the 1970s and further to 27.52 per cent in the 1980s. However, it has increased to 29.91 per cent in the post-reform period (1990s).

TABLE 1A. PERFORMANCE OF AVERAGE PRODUCTIVITY LAND

(per cent)

State	Value of Agricultural Output per Hectare (Rs.) at 1990/93 Prices (Triennium Average)					Annual Compound Growth Rate				
	1962/65	1970/73	1980/83	1992/95	1999/2002	Period 1	Period 2	Period 3	Period 4	Period 5
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Andhra Pradesh	4065	4363	6276	9391	10985	0.89	3.70	3.41	1.96	2.62
Assam	5728	6241	6907	8197	8792	1.08	1.02	1.44	0.88	1.13
Bihar	3680	4010	4049	5678	6175	1.08	0.10	2.86	1.05	1.36
Gujarat	3673	427	5693	7460	8529	2.07	2.78	2.28	1.67	2.22
Haryana	3927	5090	6229	10129	12079	3.30	2.04	4.13	2.20	2.96
Karnataka	3208	4267	4990	6970	8065	3.63	1.58	2.82	1.82	2.43
Kerala	11376	12958	12334	15626	16619	1.64	-0.49	1.99	0.77	0.99
Madhya Pradesh	2604	2836	3070	4773	5357	1.07	0.80	3.75	1.44	1.89
Maharashtra	2899	2344	3795	5177	5782	-2.62	4.94	2.62	1.38	1.82
Orissa	4114	4073	4375	5979	6427	-0.13	0.72	2.64	0.90	1.17
Punjab	5396	7467	9708	13597	16150	4.16	2.65	2.85	2.15	2.88
Rajasthan	1741	2217	2335	3715	4290	3.07	0.52	3.95	1.80	2.37
Tamil Nadu	6690	7900	8756	14074	16193	2.10	1.03	4.03	1.75	2.33
Uttar Pradesh	3970	4590	5805	8656	10021	1.83	2.38	3.39	1.83	2.44
West Begnal	5075	5615	5944	9958	11314	1.27	0.57	4.39	1.59	2.11
India	3738	4256	5090	7388	9795	1.64	1.80	3.15	2.34	2.50
CV (per cent)	50.06	51.69	43.71	41.43	41.69	101.74	89.87	27.52	29.91	30.93

Sources: Government of India (2004), Bhalla and Singh (2001), Bhalla and Tyagi (1989).

Notes: Period 1: 1962/65-1970/73; Period 2; 1970/73-1980/83; Period 3; 1980/83-1992/95; Period 4; 1992/95-1999/2002; Period 5; 1962/65-1999/2002.

Along with the changes in the level of growth rate of agricultural productivity per hectare across the states, the introduction of new technology has also brought about significant changes in the regional pattern of agricultural labour productivity. Table 1B clearly reveals that due to differential adoption of the new technology, inter-state variations in labour productivity increased considerably during the period. The CV of average labour productivity level has increased from 39.65 per cent in 1962-65 to 52.34 per cent in 1980-83 and further to 60.48 per cent in 1999-2002. Inter-state variations in the growth rate of labour productivity, although declined significantly during 1962/65-1992/95, increased after the economic reforms. The CV of growth rate of labour productivity has declined from 570.63 per cent in the 1960s to 206.54 per cent in the 1970s and further to 69.13 per cent in the 1980s, but increased to 82.31 per cent in the 1990s. The increased inter-state variations in the level of labour productivity may be attributed to the phenomenon of differential adoption of new technology in association with increased mechanisation in agriculturally advanced states. Since the HYV-technology along with modern inputs including machines was used more intensively and extensively in some regions than the others, labour productivity increased faster in the advanced regions than the less advanced ones, leading to considerable increase in the inter-state disparities of labour productivity. The effects of economic reforms might have strengthened the process. The on-going economic reforms and liberalisation of domestic and foreign trade in agricultural commodities might have induced a change in cropping pattern in favour of some states relative to others, producing significant changes in the spatial pattern of agricultural development.

Table 1C reveals large inter-state variations in agricultural development measured in terms of per capita agricultural output. Presumably, due to differential adoption of the HYV technology and the consequent differences in the agricultural performance across the states, inter-regional variations in per capita agricultural output increased significantly during the period. The CV in the growth rate of PCIA has been quite high in all the sub-periods. Moreover, the CV in the level of PCIA has increased from 18.72 per cent in 1962-65 to 41.71 per cent in 1980-83 and further to 48.41 per cent in 1992-95. It has declined slightly to 48.37 per cent in 1999-2002. During 1960/61-2001/02, there has been an overall increasing trend in the inter-state disparities of PCIA. We have computed that standard deviation (SD) and CV of PCIA across the states for each year during the period. The estimated SD of the logarithms of PCIA and CV of its levels are plotted against time in Figure 1. Both the SD and CV of PCIA depict a rising trend, which is confirmed by the results of a linear trend in SD and CV of PCIA reported below.

SD of log PCIA = 0.223 + 0.0051 t; R^2 = 0.872.
CV of PCIA = 0.23 + 0.0072 t; R^2 = 0.824.

TABLE 1B. PERFORMANCE OF LABOUR PRODUCTIVITY

	Male Worker Productivity (Rs./worker) at 1990/93 Prices (Triennium Average)					Annual Compound Growth Rate (per cent)				
State	1962-65	1970-73	1980-83	1992-95	1999-2002	Period 1	Period 2	Period 3	Period 4	Period 5
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Andhra Pradesh	6,706	6,355	7,707	9,298	9,912	-0.67	1.95	1.58	0.80	1.03
Assam	6,166	6,413	7,349	8,021	8,444	0.49	1.37	0.73	0.64	0.83
Bihar	3,860	3,500	2,965	2,934	2,774	-1.22	-1.64	-0.09	-0.70	-0.87
Gujarat	8,878	8,529	9,930	10,807	11,234	-0.50	1.53	0.71	0.48	0.62
Haryana	11,144	13,874	15,357	21,871	24,849	2.78	1.02	2.99	1.59	2.11
Karnataka	6,883	7,575	8,061	11,016	12,060	1.21	0.62	2.64	1.13	1.47
Kerala	15,576	15,657	15,586	16,830	17,092	0.07	-0.05	0.64	0.19	0.24
Madhya Pradesh	6,234	6,327	6,104	8,556	9,100	0.19	-0.36	2.85	0.77	0.99
Maharashtra	7,309	4,882	8,144	9,758	10,325	-4.92	5.25	1.52	0.71	0.91
Orissa	5,812	5,483	6,340	6,278	6,376	-0.73	1.46	-0.08	0.19	0.24
Punjab	11,302	14,950	20,646	26,967	31,723	3.56	3.28	2.25	2.03	2.72
Rajasthan	5,233	6,534	6,348	9,090	10,104	2.82	-0.29	3.04	1.32	1.73
Tamil Nadu	7,855	8,472	7,274	10,943	11,671	0.95	-1.51	3.46	0.81	1.04
Uttar Pradesh	5,513	6,032	6,801	7,773	8,309	1.13	1.21	1.12	0.83	1.08
West Bengal	5,714	5,787	5,380	7,808	8,299	0.16	-0.73	3.15	0.76	0.98
India	6,414	6,552	7,215	8,961	12,151	0.27	0.97	1.82	0.77	1.68
CV (per cent)	39.65	46.79	52.34	55.34	60.48	570.63	206.54	69.13	82.31	82.78

Sources: Same as in Table 1A.
Notes: Same as in Table 1A.

TABLE 1C. PERFORMANCE OF PER CAPITA AGRICULTURAL OUTPUT (PCIA)

	Level of PCIA (Rs.) at 1980/81 Prices					Annual Compound Growth Rate (per cent)				
State	1962-65	1970-73	1980-83	1992-95	1999-2002	Period 1	Period 2	Period 3	Period 4	Period 5
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Andhra Pradesh	660	591	667	680	805	-1.33	0.398	0.231	1.85	0.634
Assam	677	636	567	581	517	-0.623	-1.49	0.207	-1.65	-0.523
Bihar	529	492	403	345	341	-0.581	-1.6	-1.51	-0.022	-1.03
Gujarat	691	679	755	726	555	0.598	2.79	-1.32	-1.018	0.354
Haryana	891	1,214	1,250	1,575	1,441	5.136	0.837	2.269	0.81	1.299
Karnataka	613	613	681	843	932	1.242	0.951	1.499	1.313	1.212
Kerala	599	600	504	661	694	0.495	-0.78	2.699	0.182	0.336
Madhya Pradesh	664	622	604	815	780	0.469	-0.297	1.631	-0.719	1.239
Maharashtra	659	475	598	750	769	-2.68	2.627	2.151	0.161	0.876
Orissa	501	703	590	578	540	4.58	-1.39	-0.983	-0.804	-0.293
Punjab	819	1,059	1,384	1,914	1,967	1.046	2.691	2.858	1.205	2.514
Rajasthan	630	739	632	771	732	2.336	-1.024	1.561	-0.052	0.786
Tamil Nadu	418	388	391	674	719	-0.908	0.175	3.632	0.953	1.977
Uttar Pradesh	599	599	642	694	722	0.375	0.492	0.711	0.173	0.683
West Bengal	532	507	448	721	875	-0.287	-0.667	3.337	2.47	1.522
India	635	626	636	744	766	0.732	0.274	1.163	0.397	0.767
CV (per cent)	18.72	32.60	41.71	48.41	48.37	316.0	610.2	131.1	347.7	120.8

Sources: Government of India (2004), EPW Research Foundation (1998), and Chandhok and the Policy Group (1990).
Notes: Same as in Table 1A.

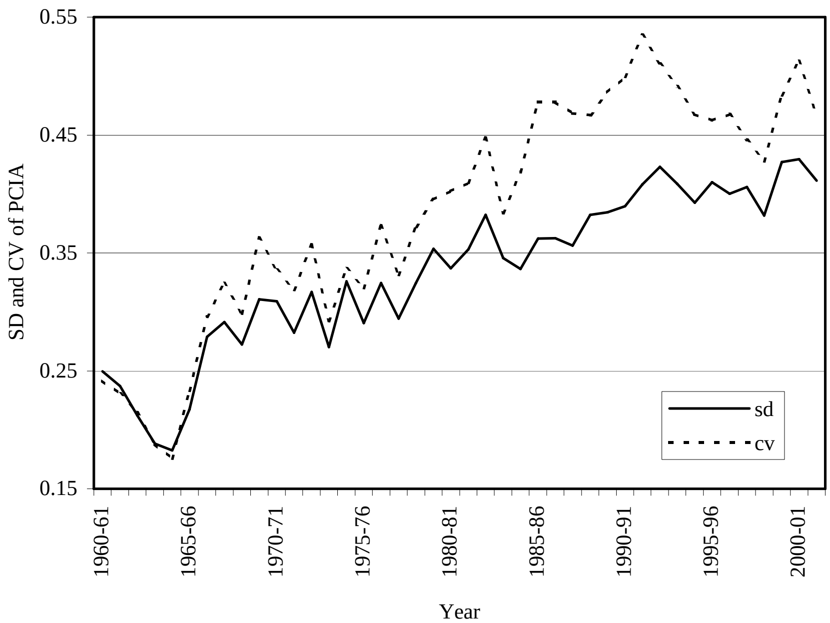

Figure 1: Time Trend in SD and CV of PCIA

The positive slope coefficients on time trend (t) and high values of R^2 suggest that the trend has been unambiguously towards greater dispersion of per capita agricultural output over time. These results are sufficient to indicate that the states have diverged in terms of per capita agricultural output during the period (σ-divergence).

Thus, although inter-state disparities in land productivity declined over time after the introduction of HYV technology, the same in labour productivity and per capita agricultural output increased significantly during the period. These results suggest that there has been a tendency of σ-divergence in agricultural development across the states. Despite the goal of narrowing of the disparities in regional development, there are clear indications of widening of regional disparities in per capita output and labour productivity in Indian agriculture during the period under consideration.

IV.2 Absolute β-Convergence

We further explore the issue of regional variations in agricultural development by undertaking tests for absolute β-convergence. The test for absolute β-convergence in land and labour productivity and PCIA is undertaken by estimating equation (1) using the data for 15 major states. The results reported in Table 2 reveal that the estimated

TABLE 2. ABSOLUTE β-CONVERGENCE IN AGRICULTURAL DEVELOPMENT

Period (1)	Constant (2)	β-coefficient on initial level (3)	R^2 (4)
Panel A: Dependent Variable: Annual Average Growth Rate of Land Productivity			
1962/65-1970/73	-0.004	0.0021	0.004
	(-0.045)	(0.231)	
1970/73-1980/83	0.009	-0.0096	0.117
	(1.551)	(-1.318)	
1980/83-1992/95	0.070	-0.0049	0.077
	(1.737)	(-1.042)	
1992/95-1999/2002	0.001	0.0016	0.021
	(0.034)	(0.534)	
1962/65-1999/2002	0.059	-0.0046	0.101
	(1.848)	(-1.207)	
Panel B: Dependent Variable: Annual Average Growth Rate of Labour Productivity			
1962/65-1970/73	-0.103	0.0118	0.054
	(-0.838)	(0.863)	
1970/73-1980/83	-0.031	0.0044	0.013
	(-0.333)	(0.416)	
1980/83-1992/95	-0.021	0.0042	0.032
	(-0.377)	(0.660)	
1992/95-1999/2002	-0.080	0.0095*	0.616
	(-4.161)	(4.568)	
1962/65-1999/2002	-0.075	0.0095***	0.165
	(-1.410)	(1.602)	
Panel C: Dependent Variable: Annual Average Growth Rate of PCIA			
1962/65-1970/73	-0.197	0.0311	0.069
	(-0.974)	(0.987)	
1970/73-1980/83	-0.067	0.0104	0.040
	(-0.739)	(0.737)	
1980/83-1992/95	0.022	-0.0011	0.001
	(0.266)	(-0.085)	
1992/95-1999/2002	0.004	-0.0006	0.001
	(0.052)	(-0.049)	
1962/65-1999/2002	-0.045	0.0079	0.026
	(-0.528)	(0.591)	

Notes: Figures in parentheses are t-statistics. * and *** denote level of significance at 1 and 10 per cent respectively. Number of observations (N) = 15.

β-coefficients for land productivity and PCIA are negative in some cases, but positive in some other cases. However, none of these coefficients is statistically significant, implying that there has been no significant β-convergence or divergence in land productivity and PCIA across the states. On the other hand, the results relating to labour productivity show that the β-coefficient is positive in all the periods, and two of these coefficients are statistically significant. These results indicate that although there has been no significant regional divergence in labour productivity during different sub-periods of 1962/65-1992/95, there has been a strong tendency of regional divergence during the post-reform period (1992/95-1999/2002). We also observe a significant tendency of β-divergence in labour productivity during the whole period (1962/65-1999/2002). Thus, although there has been no significant absolute β-convergence or divergence in land productivity and per capita agricultural output, there has been significant divergence in labour productivity, particularly after the initiation of economic reforms in the early 1990s. This suggests that while regional inequalities in land productivity and per capita agricultural output have been persisting, the same in labour productivity have been increasing during the period under consideration.

The evidence that β-convergence is statistically insignificant in most cases may be construed to be an indication that the neoclassical growth model from which the absolute β-convergence equation is derived may not be an appropriate framework for explaining the agricultural growth process in the states. This seems to be one possible reason for which the absolute β-convergence equation turns out to be inappropriate for the data in most cases. In any case, these results contradict the prediction of the neoclassical growth model, but lend support to the argument of the endogenous growth model. The endogenous growth model (Aghion and Howitt, 1992; Grossman and Helpman, 1991; Romer, 1990) argues that region-specific factors play a role in determining aggregate output, and since region-specific factors can evolve endogenously according to the environment unique to a region, regions with dissimilar initial endowments and attributes can have per capita income that does not converge over time. This directs us to examine the regional disparities in agricultural development by estimating the conditional β-convergence equation taking into account the region-specific factors underlying the growth process of the states.

IV.3 Conditional β-Convergence and Factors Behind Regional Divergence

The variations in agricultural performance across the states might be due to inter-state variations in the initial conditions of natural endowments, infrastructure, physical and human capital, etc. These variations are likely to generate different steady states for different regions, leading to inter-regional variations in agricultural performance. Therefore, with different steady states for different regions, we need to test for conditional β-convergence in order to account for the regional disparities in agricultural development. The test for conditional β-convergence can be performed only after the factors, which might have caused variation in steady states across the regions, are taken into account. Since the existence of conditional β-convergence signifies that the regions are converging only towards their own steady states, the regional variations in agricultural performance may be explained in terms of regional variations in steady states.

We have specified the conditional β-convergence equation (2) by incorporating the following conditioning variables: (a) Number of tractors per thousand hectares (*Trac*); (b) Number of pumpsets per thousand hectares *(Pump)*; (c) Consumption of chemical fertiliser per hectare (*Fert*); (d) Percentage of gross cropped area (GCA) irrigated (*Irri*); (e) Rural literacy rates (*Rlit*); (f) Net cultivated land area (*Area*); (g) Density of population (*Density*) and (h) Percentage of rural population to total population (*Rpop*). While variables (a) to (c) are used as proxies for physical capital and (d) for rural infrastructure, variable (e) is used as a proxy for educational human capital; Variable (f) may be considered as a proxy for natural endowment. The convergence equation was estimated by the OLS method for land and labour productivity and PCIA, using pooled cross-sectional data for 15 major states corresponding to four periods; 1962/65-1970/73, 1970/73-1980/83, 1980/83-1992/95, and 1992/95-1999/2002. The estimated results are reported in Table 3.

TABLE 3. CONDITIONAL β-CONVERGENCE IN AGRICULTURAL DEVELOPMENT

	Dependent Variable: Annual Average Growth Rate of		
Independent variable	Land Productivity	Labour Productivity	PCIA
(1)	(2)	(3)	(4)
Constant	0.224	0.307	0.145
	(1.459)	(1.365)	(0.630)
ln (Initial Level)	-0.0249*	-0.0067**	-0.0166***
	(-3.272)	(-1.923)	(-1.600)
ln *(Trac)*	0.0024	0.0017***	0.0027
	(1.274)	(1.674)	(0.879)
ln *(Pump)*	0.0058*	0.0019	0.0045***
	(2.767)	(0.743)	(1.486)
ln *(Fert)*	-0.0033***	-0.0036	-0.0054***
	(-1.369)	(-1.268)	(-1.634)
ln *(Irri)*	0.0106*	0.0084**	0.0119**
	(2.642)	(1.716)	(2.125)
ln *(Rlit)*	0.0098**	0.0039***	0.0071**
	(1.977)	(1.651)	(1.841)
ln *(Area)*	-0.0081**	0.0065	0.0037
	(-1.958)	(1.245)	(0.782)
ln *(Density)*	0.0024	-0.0083***	-0.0031
	(0.484)	(-1.469)	(-0.454)
ln *(Rpop)*	-0.0003	-0.0387***	-0.0235***
	(-0.010)	(-1.386)	(-1.675)
R^2	0.419	0.342	0.316

Notes: Figures in parentheses are t-statistics, *, ** and *** Significant at 1, 5 and 10 per cent level respectively. N=60.

It can be seen that the selected conditioning variables explain around 32 to 42 per cent of the regional variations in growth rates of land and labour productivity and PCIA. The estimates reveal that the initial level of land and labour productivity and PCIA has a statistically significant negative coefficient – an evidence of conditional β-convergence, suggesting that the states have been converging towards their own steady states. The speed of convergence turns out to be 2.49 per cent per year for land productivity, 0.67 per cent for labour productivity and 1.66 per cent for PCIA. As expected, the conditioning variables such as *Irri* and *Rlit* have positive and statistically significant coefficient in all the regression equations, suggesting that these variables have positive significant effects on the transitional growth rates and steady-state levels of land and labour productivity and PCIA. The variables like *Trac* and *Pump* also bear positive coefficient in all the equations, but while the coefficient on *Pump* turns out to be significant in the case of land productivity and PCIA, the coefficient on *Trac* is significant in the case of labour productivity only.

Surprisingly, the coefficient on *Fert* turns out to be negative in all the equations, and statistically significant in all the cases except labour productivity. This somewhat counter-intuitive result needs explanation. One way of explaining this result is that under the irrigation-fertiliser-based HYV-technology, farmers have the natural tendency to increase agricultural output by using fertiliser as much as possible. Evidence at the micro level suggests that farmers in several parts of India have been using fertiliser over and above the recommended doses. It is reported that the increases in agricultural production in the green revolution regions were achieved through manifold increase in chemical fertilisers with declining marginal gains. The all-India level data show that per hectare consumption of fertiliser increased considerably over time. Per hectare consumption of NPK, which was 31.83 kilograms in 1980/81, went up to 67.48 kilograms in 1990/91 and further to 90.12 kilograms in 2001/02. The practice of using excessive amount of fertiliser has been creating environmental problems in the form of soil salinisation and pollution, damaging thereby the physical and chemical structure of soil. These are reported to have been affecting agricultural productivity and output adversely.

It is obvious that due to the law of diminishing marginal productivity, the marginal effect of land area on the growth rate of land productivity would be declining. This is why we have obtained a negative and significant coefficient on *Area* in the case of land productivity. However, since land is a co-operant input in the case of labour productivity and PCIA, the coefficient on *Area* turns out to be positive, although not significant statistically. The coefficient on *Density* is found to be negative in the case of labour productivity and PCIA, but positive in the case of land productivity. It is, however, significant only in the case of labour productivity. The evidence that the coefficient on *Rpop* is negative in all the equations and significant in all the cases except land productivity seems quite interesting. This may be interpreted as an indication that crowding of people in rural areas would create pressure on land and thus lead to lower agricultural productivity and per capita output. This result has significant policy implications for rural development.

Overall, our results suggest that the states have different steady-state levels of land and labour productivity and PCIA, and that they have tendencies to converge towards their own steady states. The key finding is that the stock of human capital proxied by *Rlit*, the level of physical capital proxied by *Trac* and *Pump*, and rural infrastructure represented by *Irri* have positive effects on the growth rates and steady-states levels of land and labour productivity and PCIA. Moreover, higher the proportion of rural population, the lower would be the agricultural productivity and per capita output. Therefore, the variations in steady-state levels of the three measures of agricultural development could be largely due to variations in the levels of these conditioning variables across the states, and the persisting regional disparities in agricultural development have been due to inter-state variations in the steady-state levels of land and labour productivity and PCIA. These results are comparable to the results corresponding to 1962/65-1999/2002 reported in Table 2, the differences being due to absolute versus conditional β-convergence.

The results of our study have limitations due to the shortcomings of the methodology based on cross-sectional regression for testing the convergence hypotheses. Quah (1993a, 1993b, 1994), Bernard and Durlauf (1995, 1996) and Evans (1997) have argued that the cross-sectional regression approach may generate inconsistent estimates of convergence rate, which may lead to incorrect inferences. Quah (1993b) shows that a negative β-coefficient may be consistent with a stable variance in output across regions. Bernard and Durlauf (1996) argue that in the presence of multiple output equilibria, the regression approach tends to reject the null hypothesis of no convergence too often. Expressing doubts on the methodology based on cross-sectional convergence regressions, Durlauf (2003) argues, "statistical tests for convergence have failed to address the notion of convergence in an economically interesting sense." Since the statistical convergence may be consistent with economic non-convergence, the statistical notions of convergence do not reflect the economic notions of convergence. A problem of the convergence methodology is the failure to develop tests of convergence hypothesis that differentiate between convergent economic model and a set of non-converging alternatives. Moreover, the model of threshold externalities and growth developed by Azariadis and Drazen (1990) demonstrates that data generated by a cross-section of regions exhibiting multiple steady states may exhibit statistical convergence. However, statistical convergence even in the presence of multiple steady states is inconsistent with the economic notion of convergence. Furthermore, there exist a number of studies, which establish that the growth processes of different regions are indeed heterogeneous and non-linear. In such conditions since the use of cross-sectional convergence regressions requires strong homogeneity assumptions, empirical analysis based on such regressions involves limitations due to failure to recognise heterogeneity and non-linearities in the growth process.

Moreover, the results derived from cross-sectional convergence regressions do not provide any scope for identifying sub-groups of states that can be described as following or not following a common steady-state path of agricultural development. It is, however, important to identify sub-groups of states, which are converging to or diverging from the national average steady-state path. The primary objective of such an exercise is to examine convergence clubs. We attempt to perform this in the next section, utilising unit-root test for convergence under the time-series framework.

IV.4 Unit-Root Test and Club Convergence

In order to avoid the limitations of the cross-sectional regression method, Quah (1992), Bernard and Durlauf (1995, 1996), Li and Papell (1999) and Cheung and Pascual (2004) have advocated the use of time series methods to examine the convergence hypothesis. Under the time-series framework, convergence requires real per capita output differentials across regions to be stationary. In other words, the levels of per capita output are not diverging over time [Bernard and Durlauf (1995, 1996), Li and Papell (1999), and Evans (1998)]. Using this methodology, we examine the convergence hypothesis by evaluating the univariate time series properties of the differentials of per capita agricultural output (PCIA) of each of the 15 states relative to the all-India average (henceforth, output differential). Convergence of a state's per capita output to the national average level requires that its output differential is stationary. In this case, the test for convergence of per capita output is translated to a test for the stationarity of output differential. A test of the null hypothesis of no convergence (i.e., non-stationarity) against the alternative of convergence (i.e., stationarity) is undertaken. The null hypothesis of no convergence is expressed as:

$$H_0: X_{i,t} = [\ln(Y_{i,t}) - \ln - (Y_{*,t})] \sim I(1), \text{ for all } i = 1, 2, \ldots 15.$$

The alternative hypothesis of convergence is expressed as:

$$H_1: X_{i,t} = [\ln(Y_{i,t}) - \ln - (Y_{*,t})] \sim I(0), \text{ for all } i = 1, 2, \ldots 15.$$

where, $X_{i,t}$ is the logarithm of per capita output of the i-th state relative to the national average; $\ln(Y_{i,t})$ and $\ln(Y_{*,t})$ respectively denote the logarithms of the i-th state's and the national average per capita output. I(1) and I(0) are respectively integrated of the order one (non-stationary) and zero (stationary) processes. The Augmented Dickey-Fuller (ADF) [Dickey and Fuller, 1979, 1981] and Phillips-Perron (PP) [Phillips, 1987; and Phillips and Perron, 1988] methods are usually used to test for stationarity of a time series. It is, however, argued that while the ADF method yields a liberal test and depends on the choice of augmenting lags, the PP method is both conservative and more powerful, and not influenced by the choice of truncation lag parameters, particularly in a small sample (see Perron, 1988). In view of this and since our sample size is small covering only 42 years, we have used the PP test for a unit root, which is based on the OLS estimates of the following regression equation:

$$X_{i,t} = \mu + \beta(t - T/2) + pX_{i,t-1} + u_t \qquad \ldots(3)$$

The test statistic, $Z(\hat{p})$ which is used here to test for the null hypothesis, H_0:p = 1 is given by

$$Z(\hat{p}) = T(\hat{p} - 1) - (T^6/24D_x)(S^2_{Tl} - S^2_u).$$

where T = Number of observations.

$$D_x = \left(T^2(T^2-1)/12\right)\sum X^2_{i,t-1} - T(\sum tX_{i,t-1})^2 + T(T+1)\sum tX_{i,t-1}\sum X_{i,t-1}$$
$$-(T(T+1)(2T+1)/6)(\sum X_{i,t-1})^2.$$

S^2_{Tl} is a consistent estimator of $\sigma^2 = \lim_{T\to\infty} T^{-1} E(S^2_T), S_T = \sum_{t=1}^{T} u_t.$

S^2_u is a consistent estimator of $\sigma^2_u = \lim_{T\to\infty} T^{-1} \sum_{t=1}^{T} E(u^2_t).$

D_x is the determinant value of the matrix of the regressors. σ^2 is the long-run variance and σ^2_u is the sample variance of residuals. The limiting distribution of the test statistic considered depends on the correlation structure of the residuals, i.e., on the ratio of the two variances. When the errors are such that two variances are equal, the limiting distributions are invariant with respect to any nuisance parameters (see Perron, 1988, for details). Since the asymptotic critical values of the PP test are the same as those of Dickey and Fuller, the critical values tabulated in Fuller (1976, Table -8.5.1, p.371) are used for testing the level of significance. The PP $z(\hat{p})$ test statistic corresponds to the case of AR(1) with drift and linear trend.

The results obtained from the unit-root test for convergence supplement the evidence of persisting inter-state variations in the steady-state levels of agricultural development. The results of the PP test for a unit root in the differentials of output (reported in Table 4) clearly reveal that, while the null hypothesis of a unit root (non-stationarity) against the alternative of stationarity, can be rejected for nine states, it cannot be rejected for the remaining six states. This suggests that while nine states

TABLE 4. PHILLIPS-PERRON UNIT-ROOT TEST FOR CONVERGENCE IN PCIA

State (1)	PP Test Statistics [Z $(\hat{p})$] (2)	P-value (3)
Andhra Pradesh	-30.047*	0.0086
Assam	-37.633*	0.0016
Bihar	-29.485*	0.0097
Gujarat	-33.311*	0.0042
Haryana	-18.946	0.087
Karnataka	-33.837*	0.0037
Kerala	-17.942	0.106
Madhya Pradesh	-23.092**	0.0376
Maharashtra	-25.124**	0.0246
Orissa	-17.380	0.1181
Punjab	-12.874	0.272
Rajasthan	-28.439*	0.0122
Tamil Nadu	-13.259	0.254
Uttar Pradesh	-41.785*	0.0006
West Bengal	-12.468	0.292

Notes: * and ** denote significance at 1 and 5 per cent level respectively. The level of significance is determined using the critical values tabulated in Fuller (1976, Table 8.5.1, p.371). N = 42 (1960/61-2001/02).

(viz., Andhra Pradesh, Assam, Bihar, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan and Uttar Pradesh) share a common steady-state path with 'all-India' the remaining six states (viz., Haryana, Kerala, Punjab, Orissa, Tamil Nadu and West Bengal) have been following steady-state paths, which are different from the 'all-India' path. These six states are thus driving the regional divergence in agricultural development. The results seem to indicate the existence of two sub-groups (clubs) of states – one club consists of the nine states that are converging to, and the other club consists of the remaining six states that are diverging from the national average steady-state path.

V

SUMMARY AND CONCLUSIONS

We have examined the regional disparities in agricultural development across 15 major states during 1960/61-2001/02. The estimates of absolute β-convergence show that while there has been no significant convergence or divergence in land productivity and per capita agricultural output, there has been significant divergence in labour productivity, particularly after the initiation of economic reforms in the early 1990s. This suggests that while regional inequalities in land productivity and per capita agricultural output have been persisting, those in labour productivity have been increasing during the period under consideration. The results of σ-convergence show that although inter-state disparities in land productivity declined over time after the introduction of HYV technology, the same in labour productivity and per capita agricultural output increased significantly.

The evidence on conditional β-convergence displays significant inter-state variations in the steady-state levels of land and labour productivity and per capita agricultural output, implying that the regional disparities in agricultural development have been largely due to these variations. The key finding is that human capital (rural literacy), physical capital (tractor and pump set), and rural infrastructure (irrigation facilities) have positive, and in most cases, significant effects on the transitional growth rates and steady state levels of the measures of agricultural development. Moreover, higher proportion of rural population has been associated with lower steady state levels of agricultural productivity and per capita output. Therefore, the variations in steady-state levels of the three measures of agricultural development could be largely due to variations in the levels of these conditioning variables across the states, and the persisting regional disparities in agricultural performance have been due to inter-state variations in the steady-state levels of land and labour productivity and per capita agricultural output. The results indicate the importance of these factors in achieving higher growth rates and steady-state levels of agricultural productivity and output. Naturally, higher investment on education and irrigation by the less advanced states could be an effective way of achieving high growth rates, and in reducing regional disparities in agricultural development. The finding of the existence of two sub-groups (clubs) of states has important policy implications for achieving regional balance in agricultural development.

Received February 2005. *Revision accepted July 2006.*

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